OIL, GAS AND PETROCHEMICAL PROCESSING

Petroleum Refiner

JUNE
1959

YOUR REPORT ON API AND WPC PAPERS

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For a "Quick Look" at this issue, turn the page . . .

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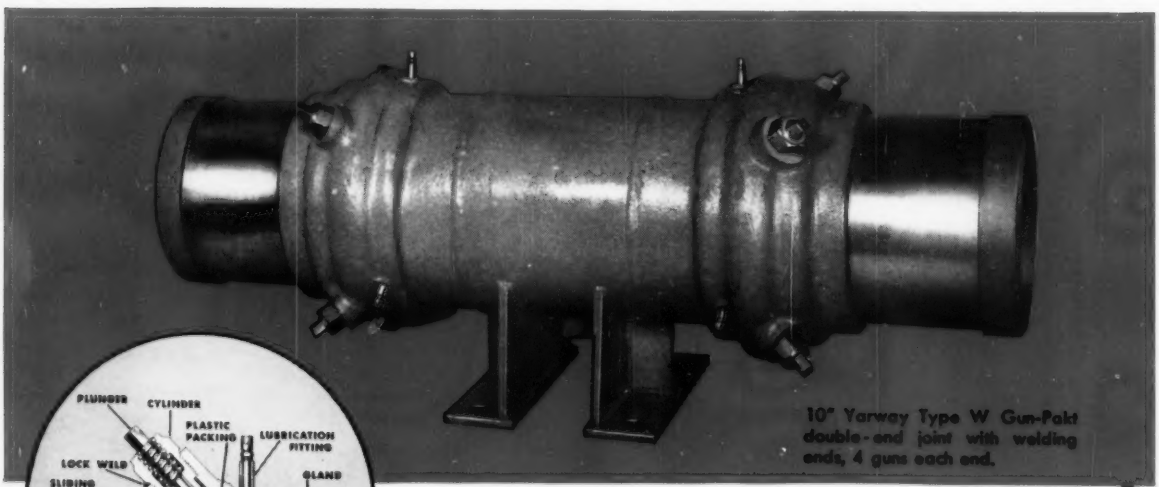
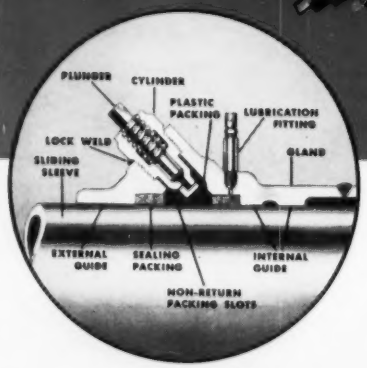


10" Yarway Type W Gun-Pakt double-end joint with welding ends, 4 guns each end.



Cross-section of Gun-Pakt feature. To add packing, just insert a plug and turn the plunger. Note non-return packing slots.

YARWAY GUN-PAKT

Volume 38, No. 6 June, 1959

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Petroleum Refiner

OIL, GAS AND PETROCHEMICAL PROCESSING

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API and WPC Special Report

☐ **Aluminizing Resists Refinery Corrosion . . .** Aluminizing carbon steel or low alloy steel selected to resist other operating conditions such as hydrogen attack, is a relatively inexpensive method of protecting against refinery sulfidation and oxidation. For comments on actual installations, turn to **Page 153.**

☐ **Extraction Goes After High Octanes . . .** The Udex extraction process is adapted to separate the high octane components from the low ones. Here are some schemes which use the Udex process for increasing the octane of a gasoline blend. Consider them when you are looking for ways to better your gasoline. Turn now to **Page 161.**

☐ **Alky Units Revamped for More Output . . .** Now you can revamp your older sulfuric acid alkylation units for greater output. In some cases the revamp is cheaper and as good as a new installation. Here are four case histories which will give you some useful ideas. Turn to **Page 165.**

☐ **When Is Delayed Coking Worthwhile? . . .** Delayed coking is a flexible process for upgrading residual fuels. Now, however, new developments and techniques permit the process to be used on heavier charge stocks than before. You'll want to review the cost data presented here to find when you can economically add coking as a part of your process scheme. See **Page 169.**

☐ **Exchange Fuel for Power and Steam? . . .** Steam and power facilities represent a substantial part of refinery investment and cost of operation, particularly if the refinery generates electricity. By trading refinery fuel for a public utility's energy, you can cut refinery capital investments and operating costs. To see how it's done, turn to **Page 177.**

☐ **Now—Dibasic Acids by Direct Oxidation . . .** Here are data on Standard of Indiana's new direct oxidation process for making polycarboxylic acids from mixed xylenes. For process details, catalysts and operating features, turn to **Page 186.**

Please Turn Page ➜

FINE PRODUCT CONTROL

is easier with a LJUNGSTROM® AIR PREHEATER

—and finer control means a more uniform, more profitable product

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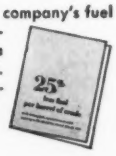

THE AIR PREHEATER CORPORATION

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A Quick Look at This Issue . . .

☐ **New Route for Dicarboxylic Acids . . .** Uses proved alkylation methods and combines dealkylation with catalytic air oxidation to produce either terephthalic or isophthalic acid in controlled amounts. For complete details, turn to **Page 189.**

☐ **More Data on Manganese Antiknock . . .** You can use the methyl derivative of cyclopentadienyl manganese tricarbonyl, MD-CMT economically to improve the octane ratings of some gasoline blends. This report tells how it can supplement TEL and what effect it will have on auto engines. See **Page 194.**

☐ **Get More Isomers at Low Temperature . . .** Esso's new isomerization process operates at low temperature to take advantage of better equilibrium conversion. This report gives you a good idea of the octanes and costs you can expect from this new process, and the data will be valuable when planning your future gasoline components. Turn to **Page 199.**

☐ **NPSH and Impeller Diameter . . .** Laboratory tests show that if head-capacity curves of a pump break at approximately the same gpm, regardless of impeller diameter, the same npsh curve will apply to both maximum and minimum impellers or any impeller diameter between. For complete details, turn to **Page 204.**

☐ **How to Design Multitube Condensers . . .** is based on the derivation of the basic Nusselt equations and modifications by Kirkbride and Katz. The resultant equations are resolved into nomogram form for your rapid solution. For better accuracy in less time, turn to **Page 205.**

☐ **Does Your Sandblasting Cost Too Much? . . .** Using the wrong sand, hose, nozzle, air supply and sandblaster will cost you about *ten times* more for the job than it should cost. Many plants today are using expensive and inefficient materials and equipment. How do your operations compare costwise? Check up on your techniques by turning to **Page 217.**

☐ **Figure Distillation This New Way . . .** (Part 1) Most multicomponent distillation calculations require a trial and error even when using a digital computer. This, the first of two articles, proposes a simple convergence method for the computer which causes a rapid approach to the desired answers. You'll find all the computational relations you need to handle a variety of multicomponent situations. Turn to **Page 221.**

☐ **Predict RVP of Blends Accurately . . .** You've always wanted a dependable way to predict easily and accurately the Reid Vapor Pressures of fuel blends. Here is one for you to use with confidence and with ease. Complete with sample problems and solutions on **Page 231.**

☐ **World's Smallest Orthoflow Cracker . . .** This smallest Orthoflow catalytic cracker is being used for commercial production in Yugoslavia. You'll get a description of the unit, a report on how well it operates, and pictures to show you the extent of corrosion. Turn now to **Page 235.**

☐ **SO_2 Extraction Plant Has Flexibility . . .** This extraction plant is located in Lisbon, Portugal. It treats a variety of stocks and makes its own solvent by burning refinery hydrogen sulfide. This article not only gives product quality data but also tells utility requirements for typical operations. Turn to **Page 239.**

☐ **Heat Transfer Nomographs . . .** (Part 9) **Water film coefficients for normal and annular flow . . .** These two nomographs permit direct determination of water film coefficients without lengthy calculations. These are for your design notebook, clip and file, turn to **Page 243.**

☐ **Prove Meters ANY TIME During Blending . . .** With this system, you can switch from one component to another during the blend run and not interrupt the run. The meter proving is a one-man operation and after the proving run, it stops automatically. To see how this unusual system works, turn to **Page 245.**

☐ **Freezing CO_2 from Natural Gas . . .** Here is a brand new idea for removing CO_2 from your natural gas plus some energy requirements for various sized plants. These show that this process may be an economical one for the treatment of the low CO_2 content natural gases. See **Page 249.**

☐ **Be Sure You Write What You Mean! . . .** If at times your writing is either misinterpreted or ignored, then more than likely you have a communications problem. Here are some helpful pointers which will enable you to greatly improve your letter and report writing. Be sure to turn to **Page 287.**

☐ **Speak Up When Disaster Strikes . . .** In times of crisis, your organization's reputation is at stake, yet in spite of this, some companies fail miserably. Here's how an enlightened management can keep a plant disaster from becoming a public relations disaster. Be sure to turn to **Page 291.**

☐ **More Information Through Documentation . . .** Engineering has matured into a dynamic force, but unfortunately, our methods of storing and retrieving information have not kept pace. For instance, how much better design could you do with all the right information? How much is duplication of engineering effort costing your company? How many times a week do you invent the wheel? For a case history on how DuPont employed documentation, turn to **Page 299.**

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For Sharp Pencil Boys

THERE IS ONE THING common in the returns of every reader interest survey which PETROLEUM REFINER conducts and that is the popularity of all discussions dealing with costs. Sharp economics, most of us agree, are essential under today's business conditions. Proposed capital expenditures cannot be checked too carefully and over-all plant economy calls for constant review. So, planned by PR for July's Special Report on Costs and Economics are articles meeting these needs like: 1) Methods of selecting projects for those investment dollars; 2) distribution of capital expansion costs so that new auxiliary units won't be overtaxed from the start; 3) use of models (Du Pont's unique plan) applied in a specific way to fit your needs. These are three of the topnotchers and there are more. So if you are one—and there are a lot of them in the processing industry—whom a $ mark attracts, then you'll want to watch out for the July Special Report.

Reprint Reliable

V. O. MARSHALL'S "Design of Foundations for Stacks and Towers" called for—and got—another hearing within the past month.

This article, first printed in December 1939 (in PR, of course) took such a hold on our engineer friends that it was published in August 1943 when a big supply of reprints were provided. This reprint stock had to be replenished several times and the demand continued in such fashion that its third publication in one of PR's regular issues was ordered (May, 1958) along with another big batch of reprints. Well, that batch proved not so big because now they are all gone and a bigger run has been ordered.

So after a brief lapse, we've got 'em again. Maybe you'd better get yours before there's a repeat lapse! Our Reprint Department, Box 2608, Houston 1 will fill all your needs at the rate of $1. per copy.

A Check Will Show

ONE OF THE MEN used by the University of Texas Extension Division in teaching the Gas Engineering Course each year at Kilgore gives his students —and they come from all parts of the world, some of them from as far away as Arabia—a bit of sound advice upon completion of the lectures:

"The best way to continue the study in this (process engineering) field is to read PETROLEUM REFINER and other technical publications."

Of course, we would be expected to agree. But let the process engineer, new and old, check for himself. Don't the men who seem to be making real progress in this field do just that as a regular practice?

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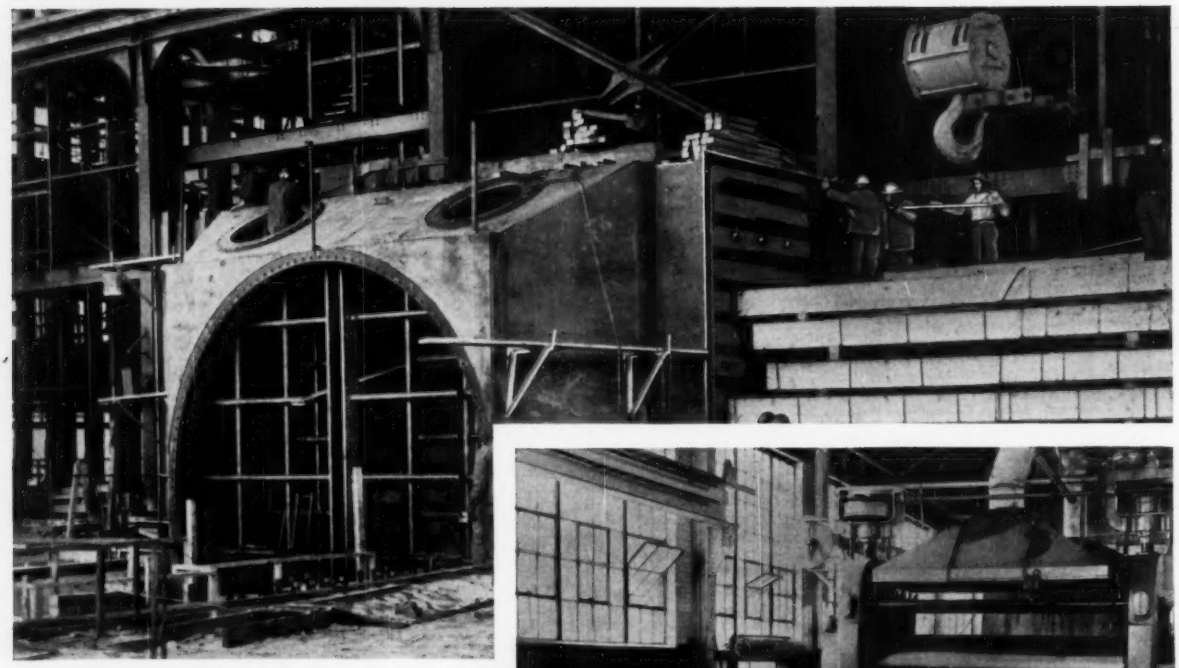

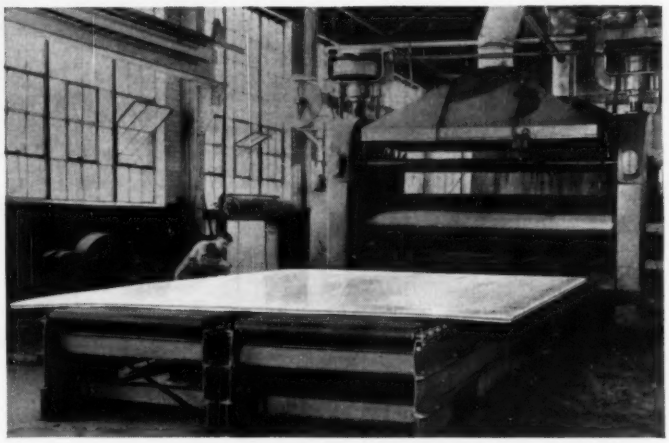

TOP: View of the new Clinch River Plant of Appalachian Power Co., at Carbo, Va. **ABOVE:** Tubing one of the two huge Allis-Chalmers surface condensers. The 26' x 15' openings in the shell use two Anaconda Leaded Muntz Metal-274 plates, each 156" x 189" x 1½" and weighing 13,700 lb. American Brass furnished the eight plates required, as well as the Arsenical Admiralty-439 tubes for the unit above — 19,100 lengths, ⅞" x .049" x 30'. **RIGHT:** The big rolling mill at American Brass Company's Detroit Division which produced the plates.

THE unusually large plates required for the tube sheets at Clinch River Plant are standard items of The American Brass Company, which produces plates of copper and a number of copper alloys in rectangular sizes up to 156 inches in width and 15,000 pounds in weight. The maximum standard limits for circles are 160 inches in diameter and 11,000 pounds in weight. Half circles can be produced up to 13,000 pounds in weight.

ROLLED PLATES SUPERIOR. Anaconda rolled plates are commercially flat, accurate in dimensions, and free from surface imperfections and porosity often prevalent in cast plates.

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Quick Look at Industry...

Quick Look at Steel Negotiations . . .

Right now, looks like steel companies hold better hand in facing union across bargaining table. Boils down to only several general routes negotiations can take—quite possibly will be one of these:

1. Acceptance of wage-price freeze by union. Almost completely out of picture. Reuther got 10-cent package for auto workers—Lewis got 25-cent hike for miners. Steel union president McDonald cannot afford to do less for his workers.

2. Settlement by June 30. This is contract deadline, but settlement by then is unlikely. Due to constant and increasing public pressure, steel management reluctant to add much fuel to wage-price fire.

3. Strike on June 30. Also unlikely, even though there is no new contract. Because of strike threat, companies built high inventories—could take 12-15 week strike without being hurt too badly. Unions know this, therefore, workers will probably stay on jobs.

4. Deferment of Strike. By putting off strike to say, September 1, unions could watch inventories slowly dwindle. If this is case, strike will last about 4 weeks—union would emerge with 10-14 cent package increase. Result: subtle steel price increases in form of "extras."

One point union and management must consider is government is watching talks real closely—Ike told both, "Don't hurt the United States." Should management or labor not act voluntarily in public interest, look for Congress to consider putting steel on semi-public utility basis—including wage and price regulation.

Synthetic Lube Use to Zoom . . .

Petroleum-based synthetic lubes will get much-needed boost in jet transport age. Newest jets use synthetic lubes entirely plus synthetic hydraulic fluids. By 1960 syn-lube demand for military should exceed 4 million gallons annually. Then tack on another 1 million a year for civilian use.

Petrochemicals Still Best Buy . . .

In spite of rising cost-of-living index at all-time high, petrochemical prices continue to drop. Last year, were at lowest since 1950. Reason: increasing production efficiency plus stiffer competition.

Chlorine Affects Redwood Cooling Towers . . .

Two independent studies, one American and one British, show delinification in redwood cooling towers results from chlorine use. Even small amounts reduce wood's ability to resist biological attack. Solution offered by California Redwood Assn: use non-oxidizing algaecide in treatment of circulating water.

Gasoline Consumption Hits New Peak . . .

U.S. gasoline consumption soared to all-time high in '58 as 22 states (up 2 from '57) required billion or more gallons each for motor

vehicles. All told, Americans burned 59 billion 154 million gallons—up 1.73 billion gallons over '57.

California led all others with 5 billion 743 million; Texas retained the No. 2 slot with 4 billion, 705 million; New York was third with Pennsylvania and Ohio rounding out the top five.

Propylene Getting Purer . . .

Look for propylene use for plastic to soar within next few years just like ethylene. This is latest prediction which accompanies improved catalysts used in purifying polymer grade propylene. Newest selective hydrogenation catalysts promise unique results in removing trace impurities from polymer-grade propylene. One such catalyst is so successful in removing methyl acetylene and propadiene that in some cases they are converted almost quantitatively to propylene, thus increasing the propylene production from 1 to 3%.

Phillips First in Mexico . . .

Pemex, Mexico's nationalized oil agency, winding up negotiations for Phillips Petroleum to build carbon black plant in Mexico. Phillips will invest 10-15% of cost while private Mexican capital (not Pemex) furnishes remainder. This marks first big investment by U.S. oil major in Mexico since expropriation of all oil properties in 1938.

Quick Look Around the World . . .

President Eisenhower exempts all overland imports of oil from mandatory controls. This affects Mexico little, Canada much . . . Conoco leases Malco Refining's Artesia, N. M. plant . . . U.S. Surgeon General Burney retracts charges that oil industry is not doing good job in fighting air pollution—says he had old information when he made criticisms . . . Ohio Oil buys Aurora gasoline for $40 million . . . Amoco sells recently-closed Destrehan, La., refinery to equipment company for liquidation.

Oil Additive Research Costly . . .

Oil companies spending much money just on fuel additives. Current survey shows research expenditures in '58 close to $21 million—about $2.70 for each barrel of crude processed.

Butyl Tires Hit Market . . .

After spending $20 million for researching, developing and testing, Esso-Humble-Enjay group has put all-butyl auto tire on market. New "no squeal" tire is another step in independence from natural rubber.

Can Atoms Free Crude from Athabasca? . . .

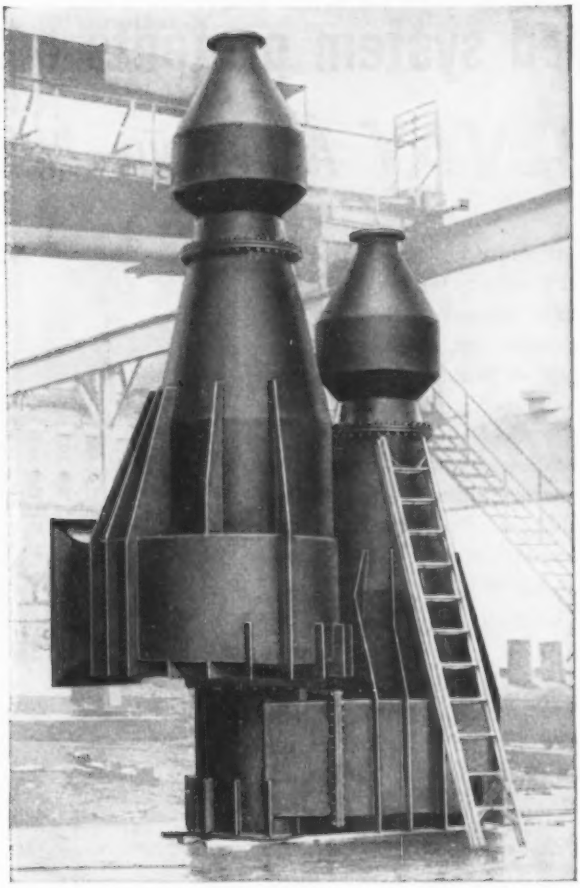
U.S. government plans two-kiloton atomic blast in Canada's Athabasca tar sands—possibly early in '60. Hopes are that project, conducted for Richfield Oil, will make 10,000 barrels of crude available for recovery at cost of $1 million.

If project succeeds, Richfield plans series of 10-kiloton hydrogen charges in huge underground blast. Estimates put Athabasca tar sand reserves at about 300 billion barrels (PETROLEUM REFINER, Jan., 1959, p. 199).

Octane Numbers to Keep Climbing . . .

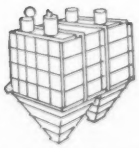
According to Ethyl Corp. official, average octanes of gasoline will continue to climb for next 5 years—possibly to heights of 102-104 for premium and 94 for regular. Attributes moderate rise in recent years to stabilization of octane requirement of new engine designs plus extra high expense per octane number at present levels. Costs from ½ to ¾ cent to raise octane of one gallon from 99 to 100.

Last month octanes continued to hold relatively steady as premium clung to 99.1 F-1 while regular climbed from 91.7 to 91.8 F-1.

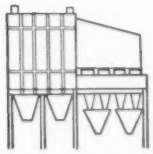


Exploring new frontiers!

BUELL CYCLONES



"SF" ELECTRIC PRECIPITATORS



PRECIPITATOR-CYCLONE COMBINATIONS

But these aren't satellite launchers, though they're specially designed for high temperature operation: they're Buell extra-efficient cyclone dust collectors . . . and the new frontiers they're exploring are in industry. Everywhere in American industry, from cement mills to refineries, from chemical plants to power generating stations, Buell collectors set new records in percentage of dust removed, low maintenance, and improved plant operation. Even in the age-old field of fly ash collection, Buell extra efficiency pays off. Only *Buell* cyclones have the unique Shave-off port that traps small fines in the double eddy currents. And Buell large-diameter design eliminates bridging, clogging, or plugging. *All three* Buell Systems are illustrated and described in "The Collection and Recovery of Industrial Dusts". Write for a copy to Dept. 21-F, Buell Engineering Company, Inc., 123 William St., New York 38, N. Y.

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Closed system protects quality of SOLVAY *Anhydrous* ALUMINUM CHLORIDE

Contamination by air can destroy the purity and reactivity we take such care to produce in Solvay® Anhydrous Aluminum Chloride. So, from production to packaging we protect it from atmospheric moisture. An example of this is the airtight chute (circled) used in loading the Solvay-designed truck for bulk shipments. Similar precautions are taken in filling the various sizes of steel drum packages to assure product quality and safe handling.

This care continues right into the customer's plant . . . through Solvay Technical Service that helps plan handling procedures and bulk storage systems. For further information, including the range of screen sizes, mail the coupon.

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MEMO TO: YOU, The Young Engineer
FROM: The Editors
SUBJECT: Plan for Self Development

IN PLANNING THE ISSUES of PETROLEUM REFINER, the editors like to think that they are playing a part in your professional development. Professional development really is a lifetime process, but these early years are most important ones. It is only natural for you to establish, as early as possible, good habits of study, of thought, of friendship and of other factors which are so important in determining your future.

We suggest that you have a positive plan to achieve your goal. First, appraise yourself to see where you are and then adopt a plan to achieve the goal you seek. Use the plan thoughtfully, with honesty to yourself, and with the determined will to carry through the sound balanced program which your own plan suggests.

Your appraisal should cover four main items:

- Your job
- Your profession
- Your personal development
- Your general program of development

You may prefer to make up your own appraisal form and list of questions. This is entirely up to you. However, The Professional and Training Committee of the Engineers Council for Professional Development (ECPD) in its brochure "Personal Appraisal," gives 40 questions concerning these four main items of interest. Below we are listing for you these 40 questions. If you are interested in other helpful professional guides for young engineers, you should write

ECPD,
33 West 39th Street,
New York 18, N. Y.

Now for the appraisal questions. We suggest you read the questions carefully and completely. Then think them over for a day or so. If any of the questions are not clear to you, talk them over with one of your older friends whose judgment you admire and trust. Then return to the appraisal and answer the questions in one or two sentences as best you can. Don't be overly ambitious about your goal—just be ambitious. You'll get there.

A. My Job

1. What are the duties and responsibilities of my present position?

2. Have I sufficient knowledge of my duties and the organization I serve to enable me to do my job well? How should I attempt to gain additional knowledge?

3. Have I the general education needed to do this job well? If not, what additional educational activity should I undertake?

4. What additional contributions, beyond the assigned duties, do I make?

5. Do I plan my work well and make every effort toward meeting this schedule?

6. Am I doing my part to maintain conditions of mutual respect and cordiality in the organization component of which I am a part? Are my understanding of responsibilities, the quality of my work, and my over-all attitude as seen by others, such as to promote these desirable conditions? Am I fully ready to share credit and to take my part of the blame?

7. Are my contacts with vendors, customers, clients, or other members of the public friendly and effective?

8. *Do I earn the friendliness and mutual respect of those for whose efforts I am responsible? *Are my instructions to them always clear and complete?

9. *Do I avoid unnecessary interference in the execution of work I have delegated to others? *Do I insist upon good work? Do I give proper credit for work well done?

10. What steps should I take to strengthen relations among my associates? Am I genuinely interested in the ambitions, problems, and well-being of my associates?

11. Have I looked for ways by which the accomplishment of my work and that of the group of which I am a member can be improved? Have I formulated any such ideas and examined them carefully? Have I taken the initiative in presenting to the appropriate people those ideas which after serious consideration still seemed sound?

12. Have my presentations to associates been clear, concise, and convincing? When my suggestions have been rejected, have I been objective in determining the reasons?

13. Does my work suffer from lack of physical vigor or from the wrong emotional attitude? How can I overcome any such handicaps?

14. For what general fields of activity am I best fitted by education, aptitude, and interest? Does my present work lead toward a career in such a field?

15. Does the organization with which I am now con-

* These questions may not be applicable to beginning engineers.

How to get a bigger share of the diesel market

Formulate superior diesel fuels using DuPont FOA-2 to reduce filter plugging

When you add Du Pont Fuel Oil Additive No. 2 to your lower grade stocks, you cut down the rate of sludge formation and greatly improve the fuel.

This is because FOA-2 is an excellent dispersant and solubilizer. It reduces the size of insoluble residue particles. The tiny particles can then flow through the system and burn with the oil. Consequently, filter-clogging and injector-sticking are greatly reduced.

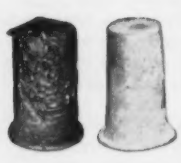
Performance tests have demonstrated the effectiveness of FOA-2. For example, in one test with a heavy cycle stock treated with FOA-2, the engines ran for 35 days without changing filters and without appreciable pressure drop. Without FOA-2, the filters became blocked in one week.

FOA-2 not only cuts sludge formation, it often cleans parts where sludge has begun to build up.

Being ashless, FOA-2 does not contribute to exhaust stack sparking.

Because of its many outstanding advantages, Du Pont FOA-2 is now being widely and successfully used by many oil companies in the diesel fuels supplied to the nation's leading railroads.

Your Du Pont representative can fill you in with further details. Or you can write for more information to E. I. du Pont de Nemours & Co. (Inc.), Petroleum Chemicals Division, Wilmington 98, Delaware.



Better filterability of FOA-2 treated fuel is shown here. The filter at the left was clogged in a week's use of untreated economy fuel. The clean filter at the right was used several weeks in an economy fuel with FOA-2 added.

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Better Things for Better Living . . . through Chemistry

Tetraethyl Lead and other Petroleum Additives

nected have the right fields of activity to offer me? Does it also offer the ideal of integrity and service, associations, and opportunities for advancement which I may reasonably expect? What advanced positions should I now prepare for? What are their duties and responsibilities? Is there any action I can take to increase or create such opportunities for myself in this organization? If not, when and where should I seek a connection with genuinely greater promise in these respects?

16. What further training, both along technical and economic or social lines, should I now begin? What added experience should I seek?

17. What personal qualities should I try to develop in preparation for advancement?

B. My Profession

18. Am I a member of my Professional Society? Do I understand its aims?

19. What requirements for the next higher grade of membership in my Professional Society do I now fail to satisfy? What steps, beyond those already planned, should I take to correct my present deficiencies? When should I plan to attain full Society membership? Are there other Professional Societies in whose activities I do or should participate?

20. What are my responsibilities to the other members of my profession? What service do they have a reasonable right to expect of me?

21. Am I taking advantage of the benefits offered to me through the Professional Societies by others of my profession?

22. Is my program of reading adequate to keep me abreast of technological progress in fields which bear on the work of my career?

23. What have I done to familiarize myself with the performance standards of a professional engineer, and how have I applied these standards to my own work?

24. Does my position and do my ambitions make it desirable for me to be a registered professional engineer? If so, what further steps should I take toward qualification; and when?

25. Am I a good representative of my profession in my community?

C. My Personal Development

26. In terms of family relationships, what are my ambitions and what goals shall I set now?

27. Are my education and cultural background adequate for the realization of my ambitions? Are my reading habits designed to enhance this background? What other methods can I use to improve myself in this area?

28. What physical, personal, or emotional shortcomings may tend to prevent full realization of my ambitions? What steps should I take to overcome these handicaps?

29. As a neighbor and citizen, what place in my community and in government should I take?

30. How should I prepare myself to carry out my community and political responsibilities?

31. Am I developing my capacity for friendship and utilizing opportunities for broadening the circle of which I am a part? Do I contribute my share toward making these social contacts valuable to others as well as to me?

32. Do I have the proper recreation, in kind and quantity, to make possible a well-rounded life for my family and me?

D. My General Program of Development

33. On the basis of this appraisal, what self-development should I undertake during the next few years?

34. How can I best utilize my present opportunities for on-the-job and social experience and what further experience should I seek?

35. What personal attitudes and qualities should I cultivate?

36. What health program should I follow?

37. What financial program should I lay out and try to carry through? What portion of my income shall I invest in my professional development?

38. In what professional, civic, and social activities should I participate and to what extent?

39. What program of sports, recreation, or avocation should I plan?

40. Do I need help in developing a program? If so, where can I get it?

Now that you've answered the above questions, don't throw the answers away. Save them. Take them out every six months or so and review them. In this way you will be able to ascertain your shortcomings. Then do your best to overcome them. You have a wonderful future to look forward to.

No Federal Aid For the Pilgrims!

NOW AND THEN you come across and are impressed by a message published under the label of advertising but containing little or no information relating to a product or service. The advertiser, in such cases, has a message of such import that he buys space in order to get it before the public. Recently, Warner & Swasey, a manufacturing firm of Cleveland, used a full page to present this powerful preachment under the caption "How much Federal Aid did the Pilgrims get?".

"They were in a Depressed Area. No one guaranteed them high prices for anything. Their only roads and schools were built by themselves. For Security they did their own saving, or starved.

"All they had was Character. All they did was Work. All they wanted was Self Respect.

"The sum of those three traits became *America.*

"But what's going to be the sum of the traits you see today—the traits of character, or, rather, lack of it, that demand more money for less work, put security above self-respect, pamper self-pitying criminals instead of punishing them, give away resources we desperately need to protect ourselves, listen to weaklings that want government to take care of them when they should take care of themselves.

"Long years of early-American self-respect and hard work built America, but the traits you see today can destroy it, in half the time."

How to Predict Octane Numbers of Multi-Component Blends

Ethyl Research Develops Equations for Calculation of Research and Motor Octane Numbers of Gasoline Blends

Accurate predictions of final blend octane numbers are necessary in any paper study of the refinery gasoline pool.

But linear calculation of final blend octane numbers generally is unsatisfactory. Volumetric average values will be higher or lower because of differences such as antiknock rating, hydrocarbon type, etc., in fuel components.

One common practice has been to introduce a blending factor to correct the final octane number. Generally, this works quite well once a given blending situation has been established.

However, none of the many techniques suggested for predicting blending deviation has proved to be so universally adaptable that it can be relied upon for broad application.

Predicting Blending Deviation by Equation. Ethyl Research has developed equations that are accurate for calculating both Research and Motor octane numbers. These equations may be applied in specific refining situations for both operating and economic calculations, or for wider, industry-type studies.

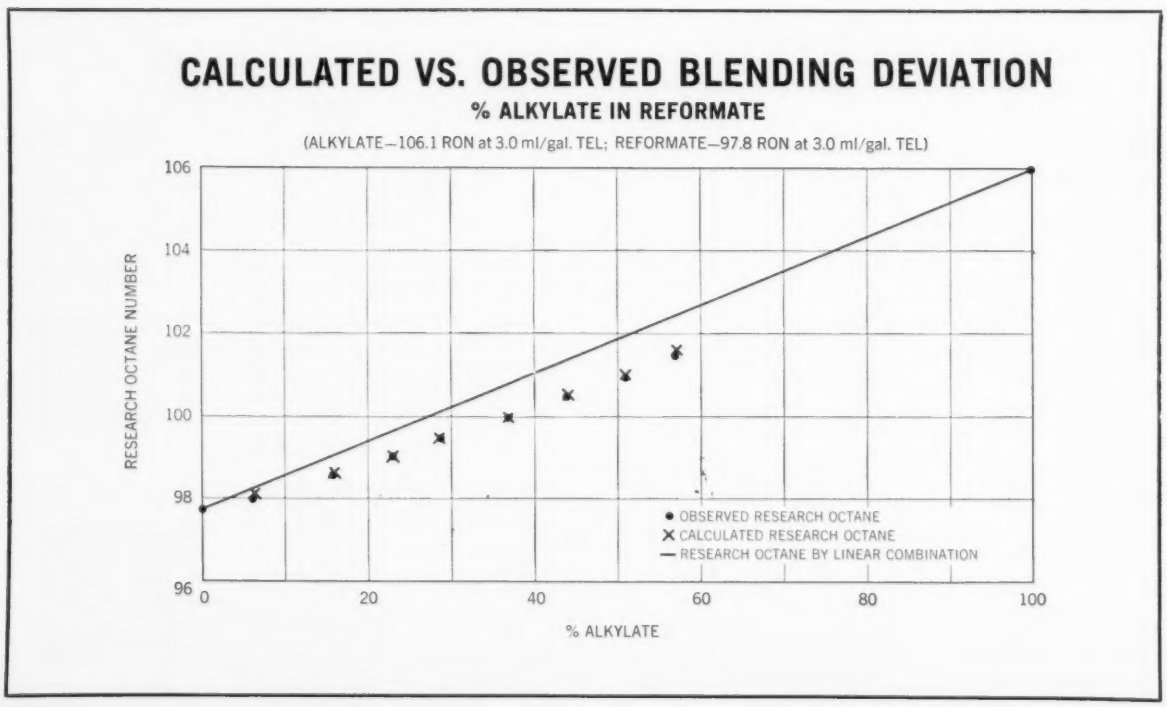
The equations fill the following requirements necessary to a good predicting technique:

They are accurate over a wide range of components and blends, since almost all possible types of gasoline components were included in the study.

They retain simplicity consistent with accuracy.

They are set up to handle different TEL levels.

While the equations were developed for use with high speed computers, they also are suitable for calculation with desk-type machines.



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The Research Octane Number Equation

The equation for calculating Research octane is as follows:

$$R = \bar{r} + a_1\left[(\bar{rj}) - (\bar{r})\ (\bar{j})\right] + a_2\left[(\bar{0^2}) - (\bar{0})^2\right] + a_3\left[(\bar{A^2}) - (\bar{A})^2\right]$$

where:

- R = Research octane number of the blend.
- r = Research octane number of each component.
- j = Sensitivity (Research octane number minus Motor octane number) of each component.
- a = Equation coefficient.
- $\bar{r}$ = Volumetric-average Research octane number.
- $\bar{j}$ = Volumetric-average sensitivity.
- $\bar{rj}$ = Volumetric-average of the product of r and j.
- $\bar{0^2}$ = Volumetric-average of the square of the olefin content in volume percent.
- $\bar{0}^2$ = Square of the volumetric-average olefin content in volume percent.
- $\bar{A^2}$ = Volumetric-average of the square of the aromatic content in volume percent.
- $\bar{A}^2$ = Square of the volumetric-average aromatic content in volume percent.

Equation coefficients have been established for use at tetraethyllead (TEL) concentrations of 3.0, 1.5 and 0.0 ml./gallon. Other TEL concentrations may be found by interpolation using TEL susceptibility charts.

A similar equation has been developed for calculating motor octane number.

Scope and Range of Development Data. Equations were developed by the method of least squares from 187 blends covering a wide range of finished gasolines. At each of three TEL levels, 135 blends out of 187 blends were selected for use in deriving and checking the blending equations. Fuels were from 24 refineries representing a good average of all U. S. facilities.

The number of components in the blends varied from 2 to 15. Component properties examined were Research octane number, Motor octane number, sensitivity, olefin content, aromatic content, sulfur content, gravity, and the 50 percent ASTM distillation temperatures.

TABLE 1 Gasoline Components Represented in Blends Used to Develop Predicting Equations

Alkylate	Aromatic Concentrate
Butane	Aromatic Raffinate
Catalytically Cracked Naphtha	C_5 and C_6 Isomers
Natural Gasoline	Pentane
Polymer	Reformate
Thermal Reformate	Thermally Cracked Naphtha

Several types of alkylate, reformate, catalytically cracked naphtha and other components were represented.

TABLE 2 Range of Properties of Blend Components and Blends Used to Develop Predicting Equations

Properties	Blend Component	Blend Range
Research Octane No.	59-113	85-105
Motor Octane No.	62-107	79-103
Olefin content, Vol %	0-100	0-60
Aromatic content, Vol %	0-96	0-70
Saturate content	0-100	25-86
Sulfur, Weight %	0-0.643	0.01-0.227

How Ethyl Research can help you

The accuracy of predictions can be improved by tailoring these equations to individual refining situations.

Ethyl Refinery Technologists are ready to work with you to establish equation coefficients from your blending data.

For an appointment with one of these specialists, see your Ethyl Representative.

Your Ethyl Representative also can supply you with a detailed engineering report of this study which served as a basis for the presentation, "A New Approach to Blending Octanes" at the New York meeting of the API, Division of Refining.

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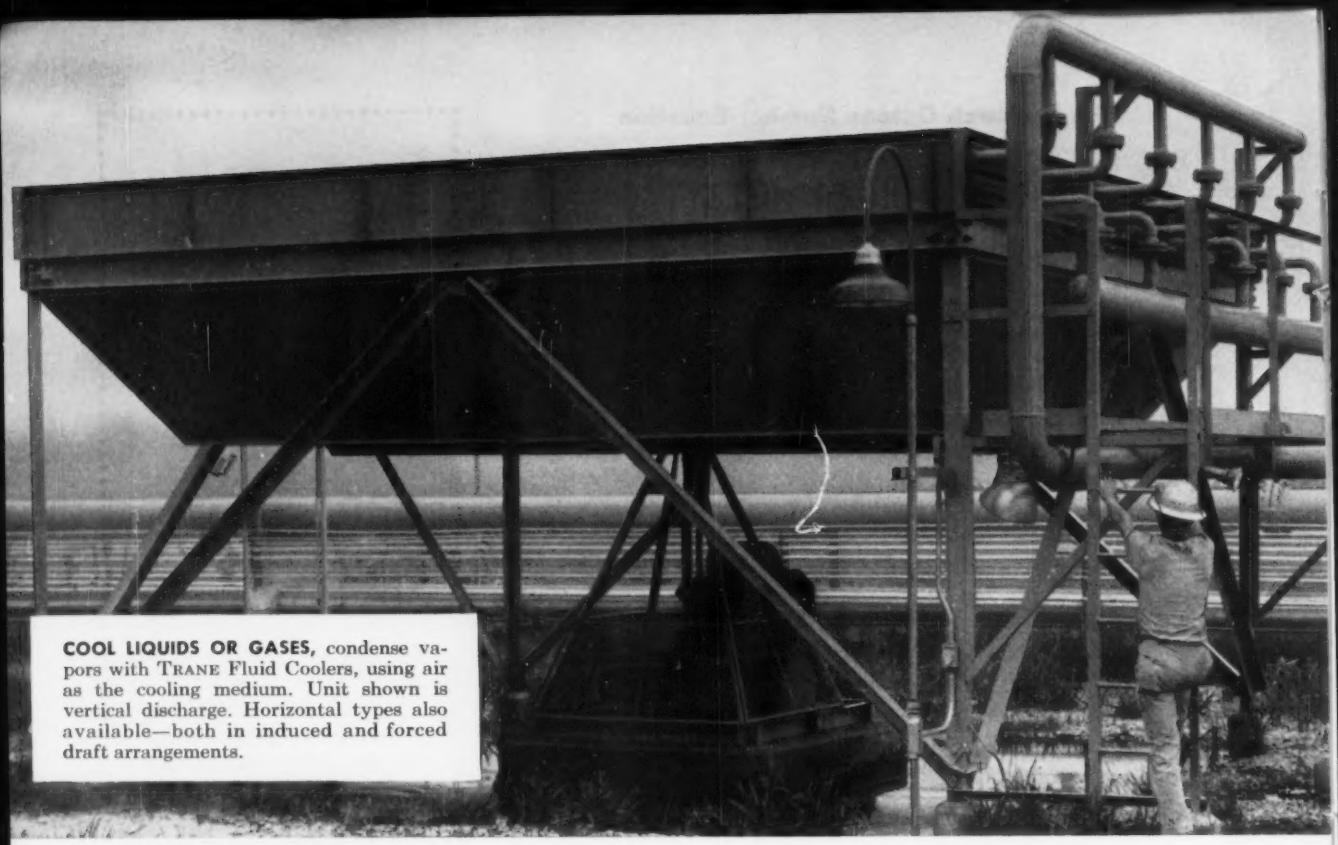

COOL LIQUIDS OR GASES, condense vapors with TRANE Fluid Coolers, using air as the cooling medium. Unit shown is vertical discharge. Horizontal types also available—both in induced and forced draft arrangements.

Lower erection costs, operating costs ...with versatile Trane Fluid Coolers!

Air-cooling now solving water supply problems for many refineries, petrochemical and natural gasoline plants

More and more engineers and plant designers are finding that *air-cooled heat exchangers* eliminate water supply and maintenance problems encountered with conventional cooling towers. These engineers report a substantial net reduction in over-all cooling costs and water consumption. Here are some of the ways TRANE Fluid Coolers are helping to solve heat transfer problems in many refineries and plants:

- **Low first cost.** Erection is simpler; fan, motor and gearbox are factory-aligned on a single metal base. Framework parts are pre-drilled, match-marked. Compact, simple, TRANE Coolers can often be installed on roofs, cutting real estate costs.
- **Lower operating costs.** Equipment needs only periodic cleaning of fin-tube surface. No need for special crews, maintenance facilities or spare parts. And TRANE Fluid Coolers have a life expectancy of 15-20 years—compared with 7-10 years for cooling towers.
- **Superior performance.** TRANE Coolers available with Admiralty stainless and carbon steel tubing to meet the most exacting specifications. Units are now in use in Canada and Bermuda—meeting extreme weather conditions. They also solve the problem of corrosion caused by salt-air atmosphere.

WANT MORE FACTS?

New Catalog S-395 has complete specification and application data on TRANE Fluid Coolers. For your copy, write TRANE, La Crosse, Wisconsin. Or just call your nearby TRANE Sales Office.

For any air condition, turn to

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MANUFACTURING ENGINEERS OF AIR CONDITIONING, HEATING, VENTILATING AND HEAT TRANSFER EQUIPMENT

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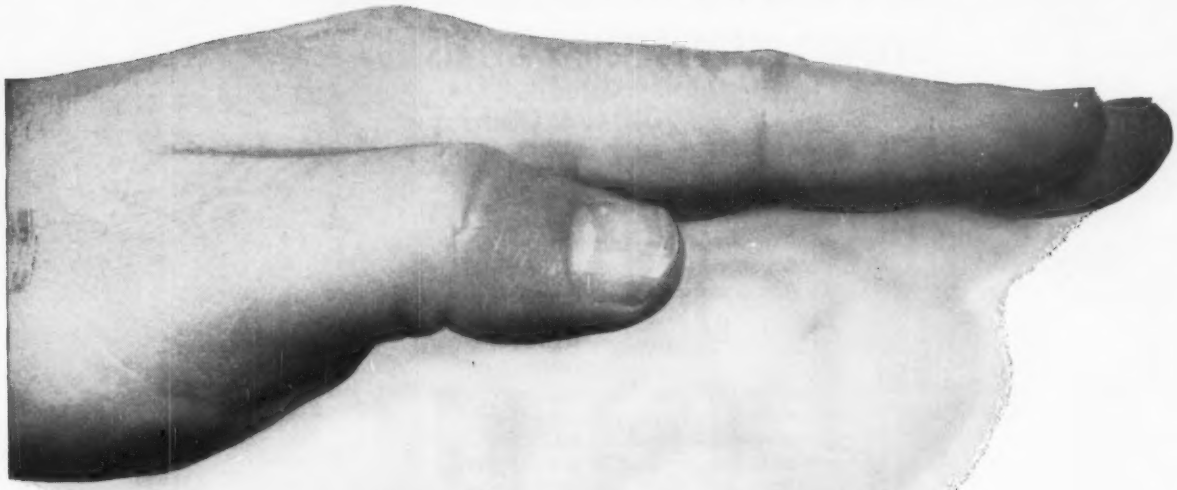
new **S&J** *Breather Valves*

Materially Reduce Storage Tank Vapor Loss



New Shand and Jurs model ST-9749 diaphragm-type breather valves are a major achievement in storage tank venting and vapor conservation. They provide resistance to sticking, corrosion and freezing never before offered. In addition they require practically no maintenance feature non-wetting teflon-on-fiberglas diaphragms for maximum performance and longer life; completely eliminate critical drain holes or other areas that require continuous checking. Ruggedly built from aluminum and stainless steel, ST-9749 breather valves are lightweight, and already available in 4″, 6″, 8″, and 10″ sizes. Call your nearest S&J branch office or sales representative for Technical Bulletin 52D-ST-9749 Breather Valve.

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Two types, "Direct Thrust" (illustrated) or "Lever" units are available for any application requiring accurate positioning in response to a pneumatic signal, such as butterfly valves, dampers, turbines and engine governors. Guaranteed positioning accuracy of better than 0.001" per inch of stroke over the complete range of piston travel is combined with a smooth operating action that provides an accurate, stable output force.

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Offered primarily for the control of variable speed drives, rheostats, pumps and cams, as well as control valves, with strokes up to 6 inches and forces up to 2510 pounds of thrust. Compact and rugged, for easy mounting on existing equipment. May be operated from a standard 3-15 psi instrument signal, with a positional accuracy within 0.001" per inch of stroke.

10,000 SERIES PNEUMATIC-HYDRAULIC ACTUATORS

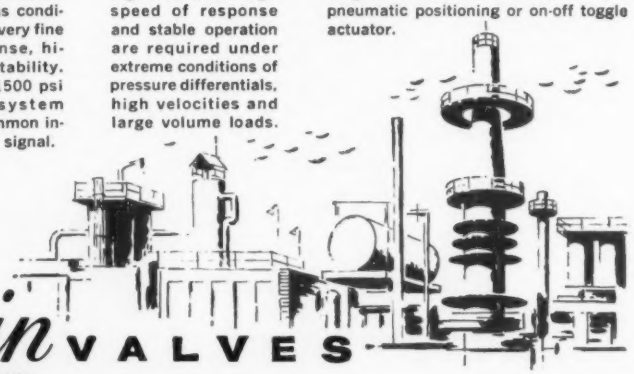
For valves requiring strokes to 6 inches and thrusts to 100,000 lbs. Furnished on body assemblies where process conditions require very fine valve response, hi-speed and stability. Operate on 1500 psi oil supply system from any common instrument air signal.

20,000 SERIES ELECTRO-HYDRAULIC ACTUATORS

Provide a means of converting an electrical signal to a powerful hydraulic positioning force, where high speed of response and stable operation are required under extreme conditions of pressure differentials, high velocities and large volume loads.

TOGGLE ACTUATORS

For process requirements where the unbalanced forces are extremely high, or where large through-puts are required. Three types are offered: pneumatic positioning, pneumatic on-off, and manual control, all embodying the toggle actuator; or a manual control arrangement can be combined with the pneumatic positioning or on-off toggle actuator.



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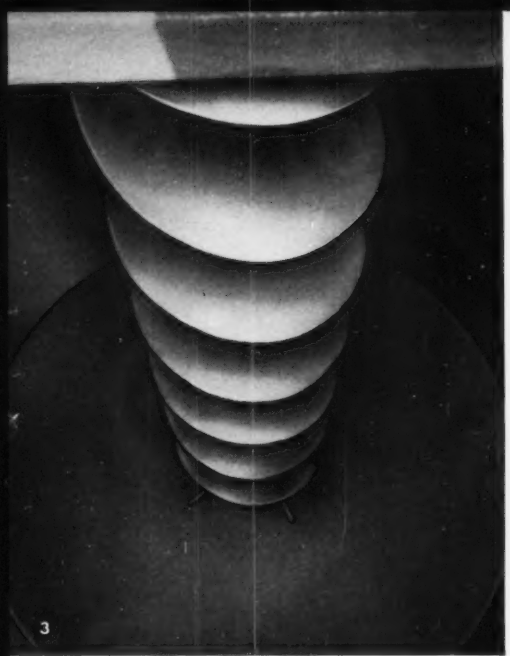
THE ANNIN COMPANY
1040 S. Vail Avenue, Montebello, California

Improved Processing through Engineered Agitation

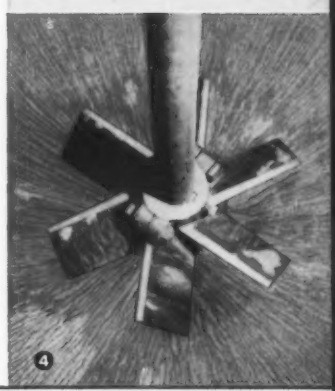


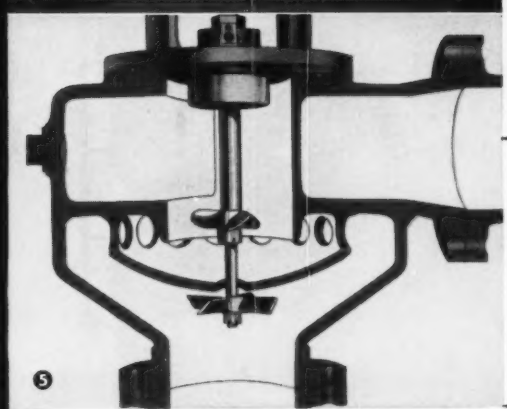
IMPELLER SELECTION . . . THE INSIDE STORY OF GOOD MIXING

THE DESIGN AND PERFORMANCE OF THE IMPELLERS are major factors in the success of process mixers. Determining the right impeller requires a thorough knowledge of below-the-surface action of different impellers in a wide variety of fluids of different density and temperatures.

THROUGH CONTINUOUS RESEARCH AND EXPERIENCE . . . gained in thousands of pilot runs and working installations . . . NETTCO has acquired the impeller know-how so important to efficient mixing. And this below-the-surface know-how can cut your processing costs by minimizing horsepower requirements!

YOUR NETTCO REPRESENTATIVE CAN HELP YOU make your process more efficient . . . more profitable. See Chemical Engineering Catalog or Refinery Catalog for his address or write for Bulletin 581, New England Tank and Tower Co., 81 Tileston St., Everett 49, Mass.





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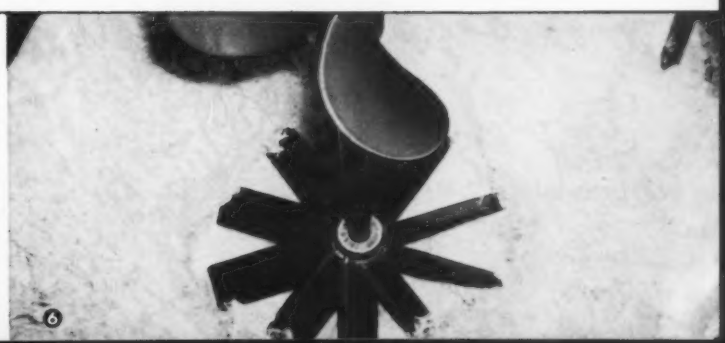
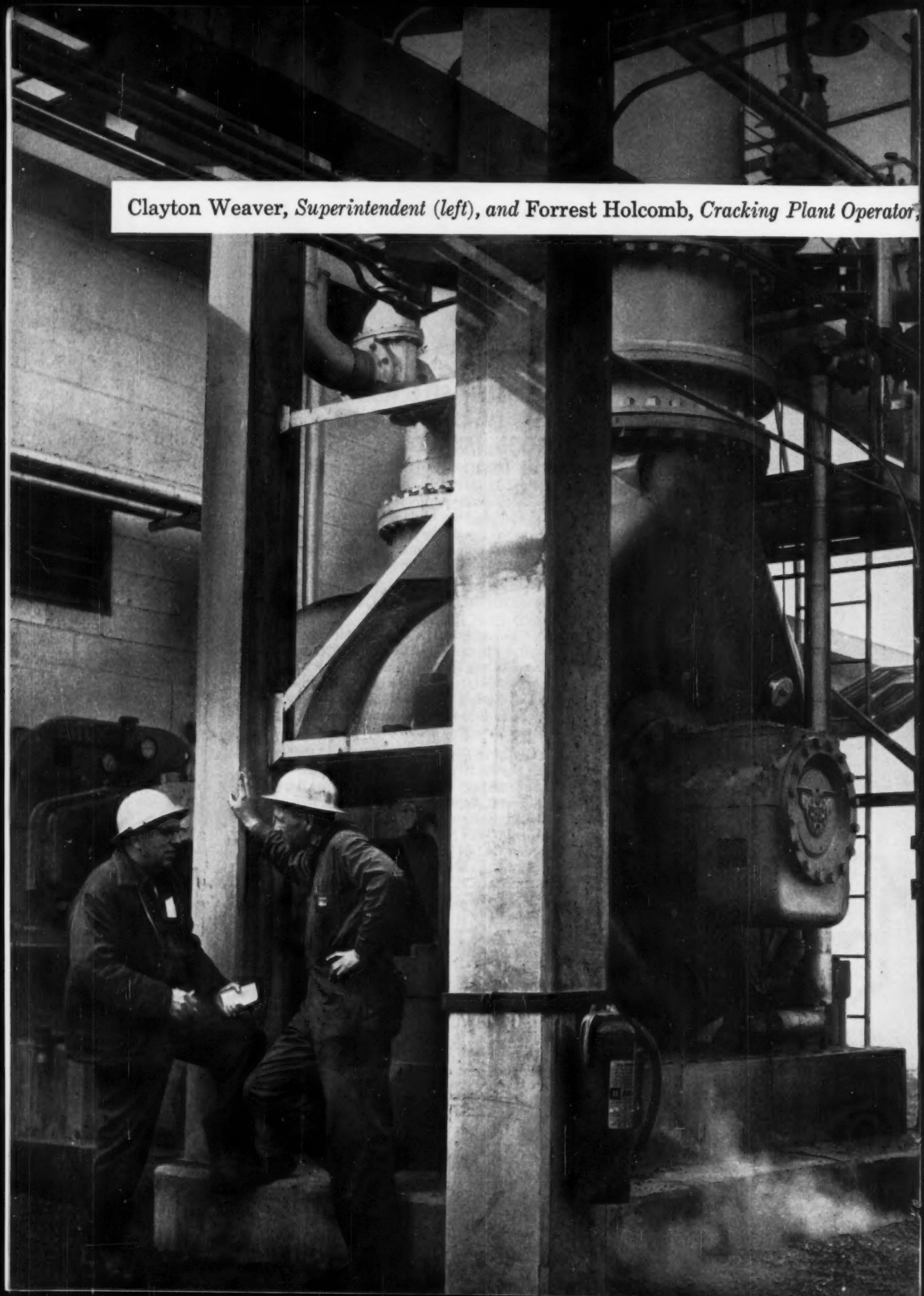
3. Corrosion-proof, plastic covered flight impeller which automatically provides variable agitation for variable tank volumes.
4. Split turbine stirrer designed for pressure tanks where minimum tank opening size is necessary.
5. Flomix impellers for continuous pipe line mixing of solids and medium to low viscosity material.
6. Standard turbine and propeller combination provides vigorous agitation for solid suspension, heat transfer and blending.





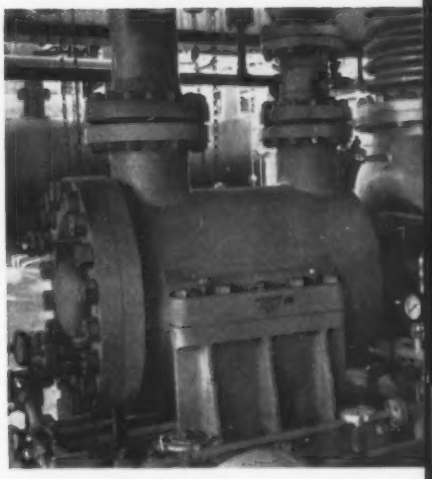
Clayton Weaver, *Superintendent (left), and* Forrest Holcomb, *Cracking Plant Operator*

Leonard Refineries, discuss function of air supply in catalytic cracking and...

How Cooper-Bessemer centrifugal compressor supplies big-volume air 'round-the-clock

As "Doc" Weaver, Superintendent of Leonard Refineries, Inc., Alma, Michigan explains . . ."Big centrifugals are the answer, of course, where modern processing calls for an extremely dependable air or gas supply at high volume and relatively low pressure. For example, our catalytic cracking requires this kind of air supply for burning coke off the catalyst. Our Cooper-Bessemer Type RS Centrifugal Compressor delivers 31,500 cfm at 30 psi discharge pressure. And, it produces this flow on a continuous, 24-hour basis. We are mighty pleased with its reliable performance."

Find out how Cooper-Bessemer Centrifugal Compressors can help solve *your* processing, air supply or compression problems for optimum economy. There is a type and size of unit for every need. Call our nearest office for complete details.



Cooper-Bessemer Centrifugal Compressors are available in multi-stage type for volumes up to 100,000 cfm . . . in barrel type for air or gas supply at pressures up to 5000 psi. Also in pipeline boosters in ratings up to 20,000 bhp. Shown above: Cooper-Bessemer barrel type centrifugal compressor.

BRANCH OFFICES: Grove City • New York • Washington • Gloucester • Chicago Minneapolis • St. Louis • Kansas City • Tulsa • New Orleans • Shreveport • Houston Greggton • Dallas • Odessa • Pampa • Casper • Seattle • San Francisco • Los Angeles

SUBSIDIARIES:
Copper-Bessemer of Canada, Ltd. . . . Edmonton • Calgary • Toronto • Halifax
C-B Southern, Inc. . . . Houston
Cooper-Bessemer International Corporation . . . New York • Caracas • Mexico City

Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

ENGINES: GAS - DIESEL - GAS-DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL, ENGINE OR MOTOR DRIVEN

Symbolized here is the uncontrolled (multi-point and premature) surface ignition on hot engine deposits that results in abnormal pressure rise and engine noise in some high-compression automobile engines. Driving conditions breed a problem too. Start-and-stop driving that builds excessive deposits is prime offender.

ATTACK ON A NEW KIND OF ENGINE KNOCK...

Celanese compounds modify engine deposits, improve combustion, reduce noise

Two great industries face a real problem in uncontrolled combustion—which results in a rumbling vibration in the higher compression engines of some of today's automobiles. This new kind of engine knock not only disturbs car owners — it puts limits on compression ratios, gasoline composition, and potential engine efficiency.

Among fuel additives researched to combat abnormal combustion, only the organo-phosphorus compounds have been able to help; they modify the composition of hot engine deposits, thus control surface ignition, and reduce excessive pressure and engine "screaming."

Since the first phosphorus additives were introduced into motor fuels a few years ago, Celanese has been a leading supplier to a growing number of gasoline refiners. And indeed, phosphates — which we have been producing for 35 years—are only one member of a huge family of Celanese chemicals basic not only to the automotive and petroleum industries but to scores of others as well.

Whatever *you* produce, whatever your problem, perhaps there is some way in which we can serve you, too. Celanese Corporation of America, Chemical Division, Dept. 574-F, 180 Madison Ave., N.Y. 16.

Celanese®

Basic reasons .....

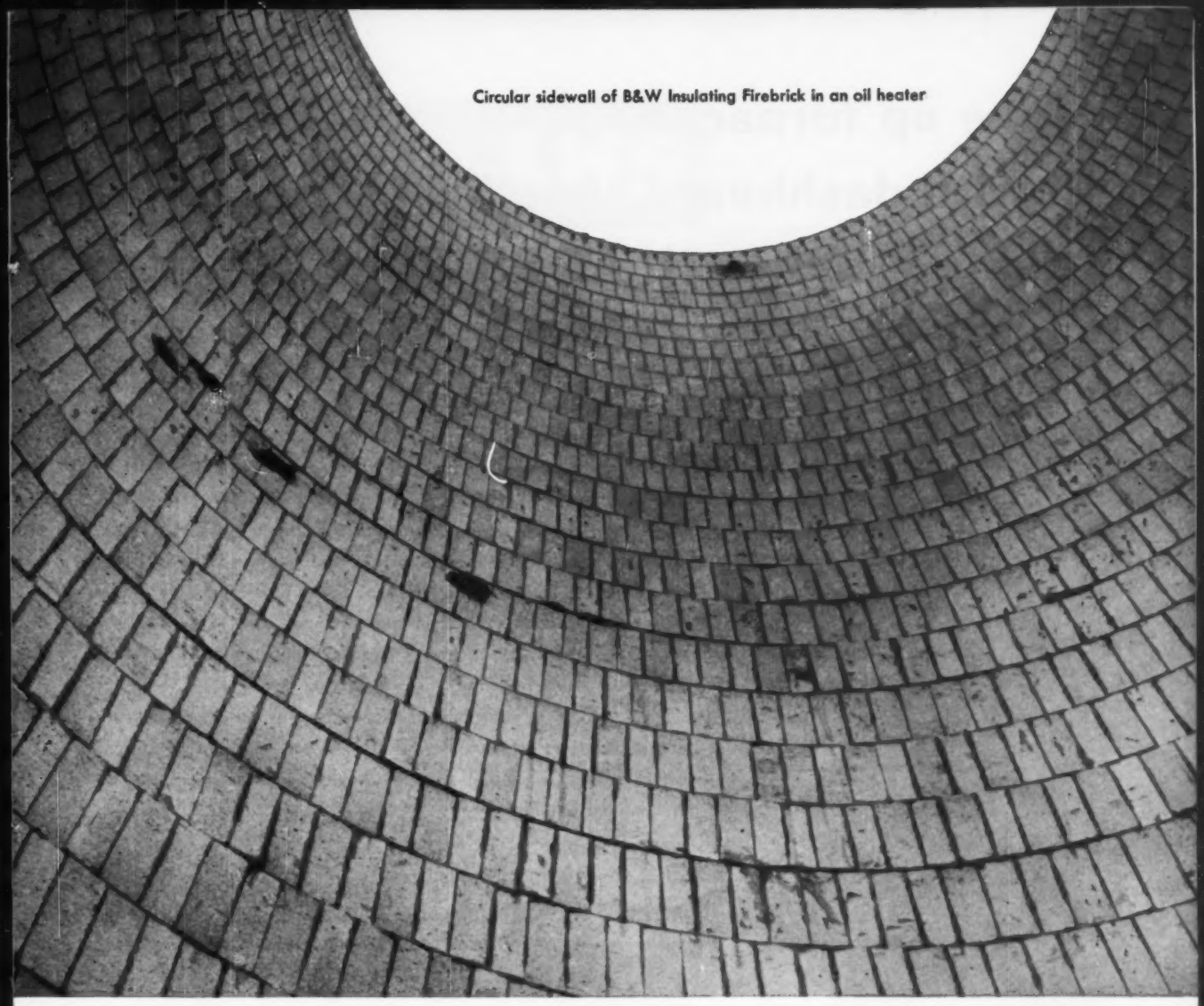
Acids	Functional Fluids	Polyols
Alcohols	Gasoline Additives	Plasticizers
Aldehydes	Glycols	Salts
Anhydrides	Ketones	Solvents
Esters	Oxides	Vinyl Monomers

Celanese CHEMICALS

.....for improved products

Agricultural	Paper
Automotive	Pharmaceutical
Aviation	Plastics
Building	Surface Coating
Electrical	Textiles

Export Sales: Amcel Co., Inc., and Pan Amcel Co. Inc., 180 Madison Avenue, New York 16, N.Y. • Canadian Affiliate: Canadian Chemical Company Limited, Montreal, Toronto, Vancouver



Circular sidewall of B&W Insulating Firebrick in an oil heater

How B&W Insulating Firebrick cut processing costs

Here are four *key* reasons why B&W Insulating Firebrick reduce over-all costs in chemical and petroleum process furnaces:

High Hot Load Strength —B&W IFB provide maximum load-bearing capacity *under operating temperatures.* Many oil heaters have been built with walls 80 feet high *with no intermediate support.*

Low Heat Storage — Cost-cutting B&W IFB have the *lowest* heat storage of any insulating firebrick. Since B&W IFB cool off fast, they protect expensive alloy tubes in the event of forced shut-down . . . make possible quick access to the furnace for inspection. They also reach operating temperature quickly, reducing cycle time and fuel bills.

Long Life — B&W Insulating Firebrick are *long* lasting because of the exceptional refractory nature of their base ingredients and the high processing temperatures to which they are subjected during manufacturing.

Short Installation Time —You save materially with B&W Insulating Firebrick because they are machined to size. They may be modified to fit door openings, peepholes, and other special conditions because they can be cut, drilled or shaped on the job with ordinary woodworking tools.

These sound reasons explain why process furnace builders and operators specify B&W Insulating Firebrick. Learn how these lightweight brick can help you save money. Your B&W representative will be glad to give you facts and figures.

BABCOCK & WILCOX

THE BABCOCK & WILCOX CO.
REFRACTORIES DIVISION
GENERAL OFFICES: 161 EAST 42nd ST., NEW YORK 17, N.Y.
WORKS: AUGUSTA, GA.

B&W REFRACTORIES PRODUCTS:
B&W Alimul Firebrick • B&W 80 Firebrick • B&W Junior Firebrick • B&W Insulating Firebrick • B&W Refractory Castables, Plastics and Mortars • B&W Silicon Carbide • B&W Ramming Mixes • B&W Kaowool

R-615

Tune up furnaces with dashboard simplicity Using a Bailey HEAT PROVER Analyzer

• For fast accurate combustion analysis, compare this portable unit to Orsat measurements: It tells you **what's happening** as you make furnace, kiln, or engine adjustments, **not what happened!** No guessing, no spot readings to average. Simple, convenient to use.

The continuous readings from a Bailey HEAT PROVER Analyzer enable operators to correct combustion variables before costly losses are incurred. The two meters on the analyzer show per cent by volume of oxygen and combustibles on either a 20% range span or a more sensitive 4% range. Temperature of the gases in degrees Fahrenheit may also be shown.

To order or get additional facts, write us direct or contact any of our District Offices. You'll find them listed in Chemical Engineering Catalog, Refinery Catalog, Thomas Register, or Mechanical Catalog.

Gas analysis with Bailey HEAT PROVER Analyzer at a process heater. Per cent oxygen and combustibles is shown continuously while testing.

CP106-1

Chemical and petroleum division

BAILEY METER COMPANY

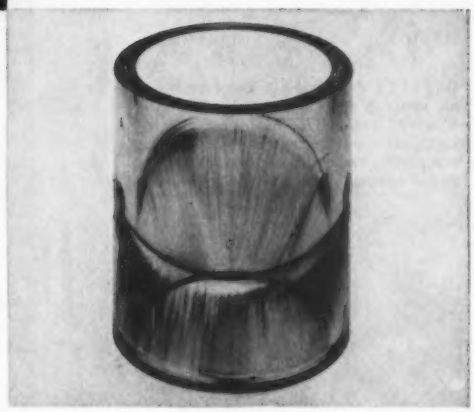
1043 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

UNICOR®-LHS

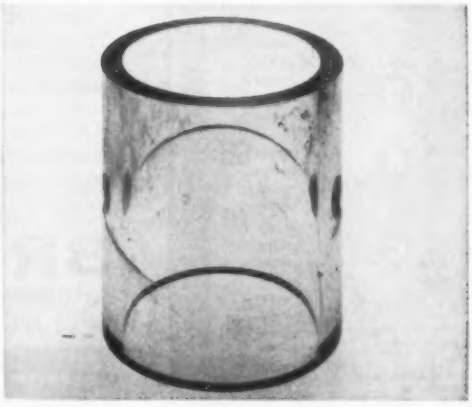
Highest Detergent Activity in an Anti-Icing Agent

The three photos on the right were taken of glass throttle bodies at the conclusion of a carburetor cleanliness test in which the additives, at low anti-icing dosages, were compared on an equal cost basis.



No additive

Best competitive detergent additive



Unicor-LHS

Sure-fire prevention of carburetor icing—*plus* positive prevention of carburetor clogging! That's what you give your customers when you safeguard your gasoline by adding Unicor-LHS.

In addition to its well-known anti-icing and corrosion-protective characteristics, Unicor-LHS provides ideal detergency action. Recent tests at Universal's laboratories (see photos at right) demonstrate that Unicor-LHS imparts greater detergency to your fuel than the best competing additives.

Convenient and economical to use, this anti-icing additive can be introduced anywhere—refinery, bulk plant or filling station—at less than half the cost of ordinary anti-icers.

We shall be glad to determine the exact anti-icing and carburetor detergency requirements of your fuels.

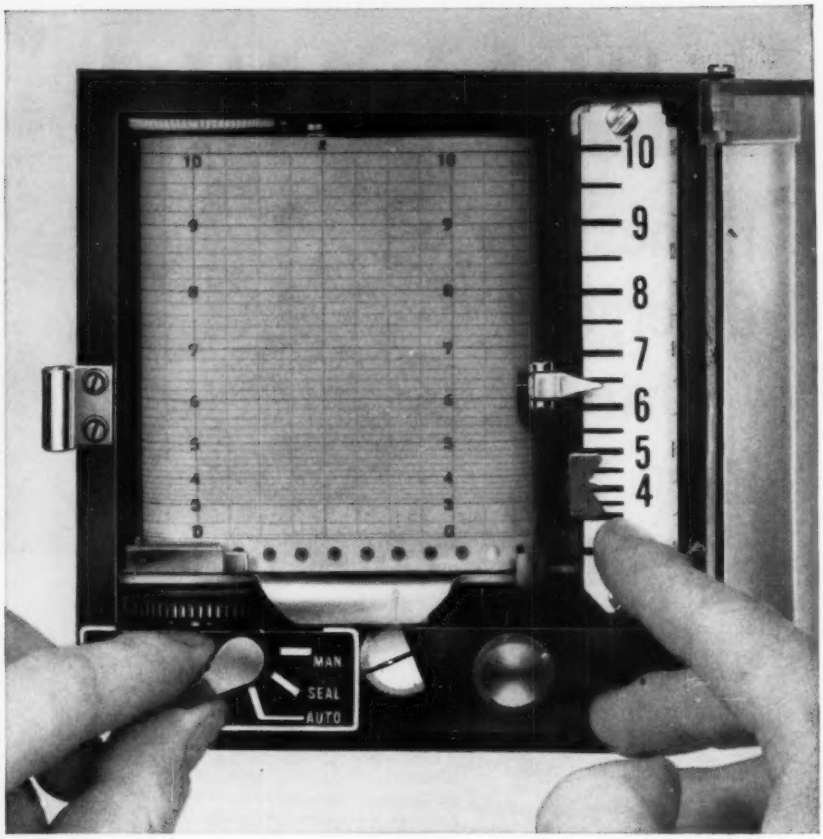
For detailed information, samples, or commercial quantities, write to our Products Department.

UNIVERSAL OIL PRODUCTS COMPANY
30 Algonquin Road, Des Plaines, Illinois, U.S.A.

More Than Forty Years Of Leadership In Petroleum Refining Technology

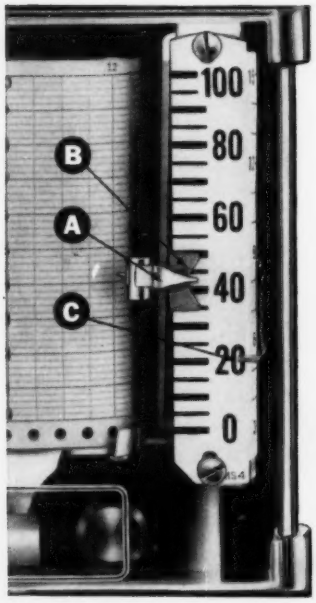
For more data on advertised products, use Readers' Service Cards, last page.

One of 38 Metagraphic Receiver Models you can choose from, all with only 5" x 5⅛" panel. This model has single-knob, six-position transfer station for completely "bumpless transfer" in cascaded control systems.



BRISTOL METAGRAPHIC RECEIVERS:

"Easiest 'bumpless transfer' you ever saw"



Variable (A), set point (B), and valve position (C), all on same scale, make manual-automatic transfer easy.

That's what instrument men say after trying the Bristol Metagraphic Pneumatic Receiver—even in cascade control systems.

Just seal, match pointers, transfer. There's not a single value to read. That's because the Metagraphic gives you valve position, set point and measured variable *—all on the same scale.*

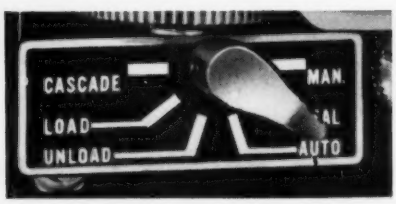
No finger-disconnects here! The Metagraphic is a true plug-in receiver—plugs and unplugs in 5 seconds with no loss of automatic control.

You can switch from indicator to recorder in less than 10 seconds, interchange many receiver models, change range simply by changing chart. Cuts down on costly reinstallations if process requirements are changed.

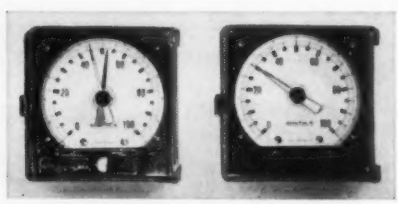
Write today for the complete Metagraphic story. Don't forget, Bristol offers the widest selection of miniatures on the market. (Full sized instruments, too.) The Bristol Company, 111 Bristol Road, Waterbury 20, Conn. B-18

BRISTOL TRAIL-BLAZERS IN PROCESS AUTOMATION

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

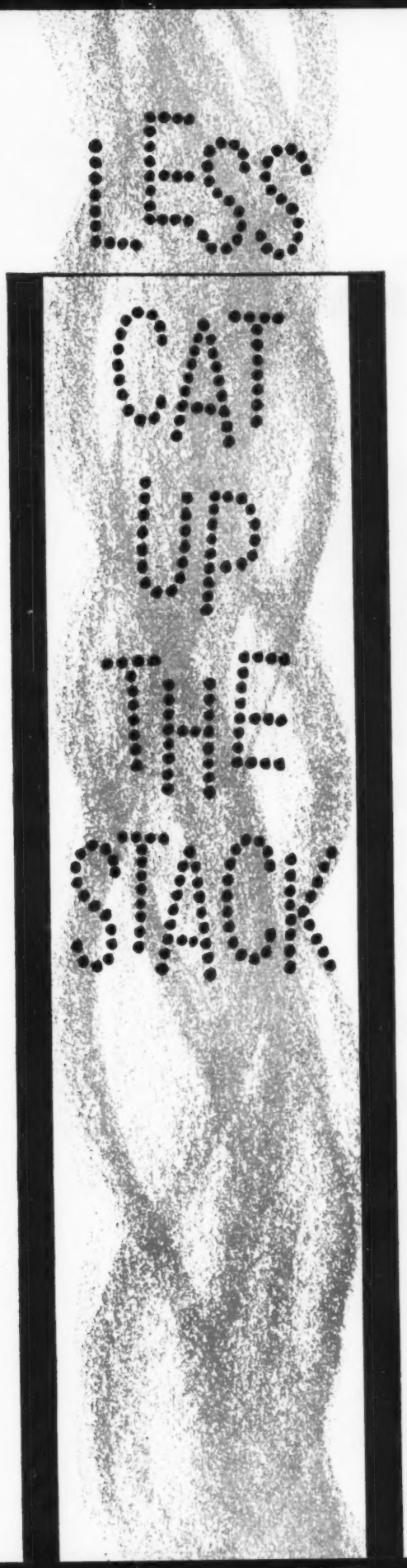


Six-position transfer station (enlarged view) for cascade service. Three-position manual-automatic station is also available.



Metagraphic Indicating Receivers have full 9-inch scale for easy reading; feature complete 10-second interchangeability with recorders.

For more data on advertised products, use Readers' Service Cards, last page.



with Davison Catalysts

Your stack carries away regeneration gases —not catalyst—when you put Davison in your unit. Here's why:

With Davison Catalysts you get the lowest amount of unretainable fines.

With Davison Catalysts you get lower attrition. The lower breakdown rate of Davison Catalysts means you get the fines you need without light particles escaping up the stack.

The reason: *balanced density*. There's a Davison Catalyst to suit your application. Write Department 391-P today for Product Service Bulletin No. 59-101.

W.R. GRACE & CO.
DAVISON CHEMICAL DIVISION
BALTIMORE 3, MARYLAND

MANY NATIONALITIES

HAVE WORN THE FW HELMET

MEN of 43 nations—from Edmonton to Rio, from Fawley to the Philippines—have been constructing Foster Wheeler process plants for 45 years. Trained by Foster Wheeler's construction experts, national workers have worn their FW helmets with pride—developing new skills and abilities and helping to enrich their countries' economies.

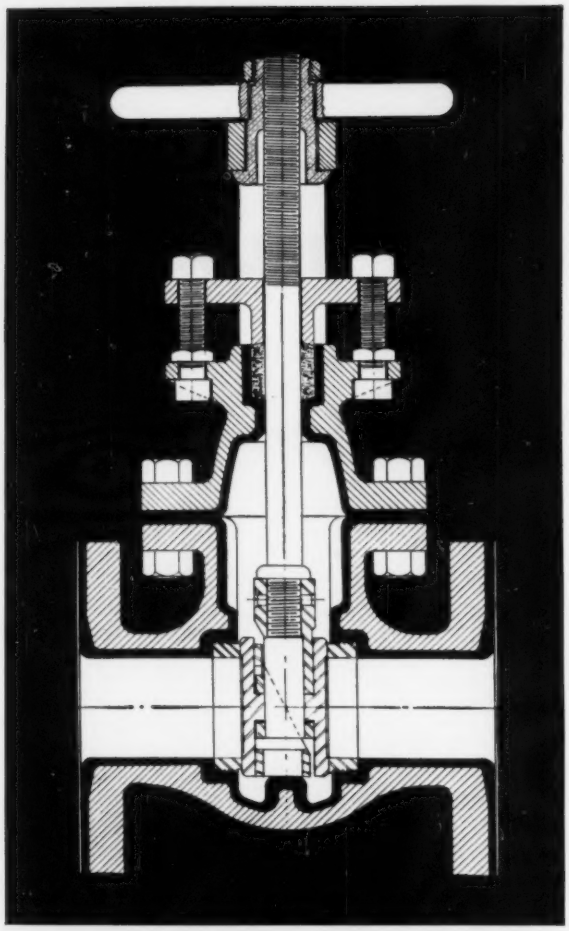
The result—more than 800 process plants on stream or under construction all over the world, including every type of refining process known to the petroleum industry.

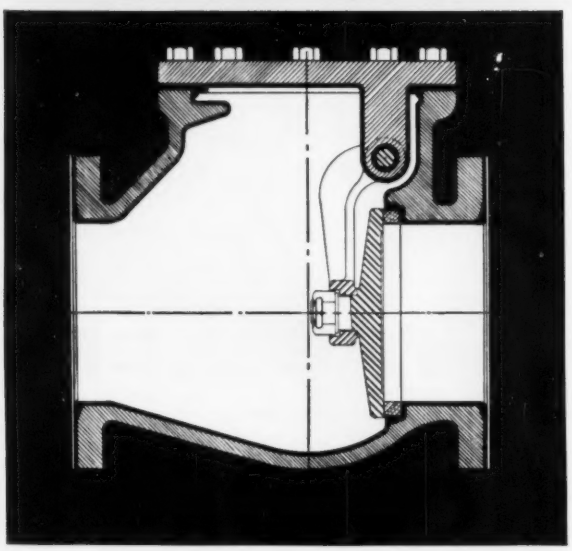
In almost a half century of design, engineering and construction work Foster Wheeler has accumulated a world of specialized technical know-how that can help you get on stream *on time*—with a complete new plant, modernization of existing facilities or the addition of individual process units. Foster Wheeler also supplies process equipment, steam generators, condensers, cooling towers and nuclear energy components.

Foster Wheeler Corporation, 666 Fifth Avenue, New York 19, N.Y.

FOSTER WHEELER

NEW YORK • LONDON • PARIS • ST. CATHARINES, ONT.





COST-CUTTERS FOR CORROSIVE SERVICE

Why pay for expensive special alloy valves when IRON BODY VALVES with hard rubber lining may solve your problem more economically?

RUBBER-LINED IRON BODY GATE VALVES

In many cases, you can save the cost of expensive alloy valves for corrosive or abrasive service. Darling rubber-lined gate valves offer you these advantages:

1. Iron body substantially reduces cost over special alloy valves.
2. Special hard rubber lining on bodies and bonnets (see diagram) provides high resistance to corrosion and abrasion.
3. Revolving double disc parallel seat and "no pocket" discs provide positive sealing and assure ease of operation.

Available in outside screw and yoke type, in sizes from 2" to 24". Write for further information.

RUBBER-LINED IRON BODY CHECK VALVES

Streamlined body design has been especially selected for application of hard rubber lining. Excess area through the valve minimizes abrasion and assures full delivery of line capacity.

A slight pressure on the pump side of the valve will immediately unseat the disc. Yet valve remains tight when there is no differential pressure on either side of disc.

Interior working parts are made of suitable corrosion resistant alloy. Yet the iron body substantially reduces overall cost.

Designed for 175-lb. working pressure. Available in sizes from 2" to 24". Write for further information.

DARLING VALVE & MANUFACTURING CO.

Williamsport 31, Pennsylvania

Manufactured in Canada by Sandilands Valve Manufacturing Co., Ltd., Galt 19, Ontario

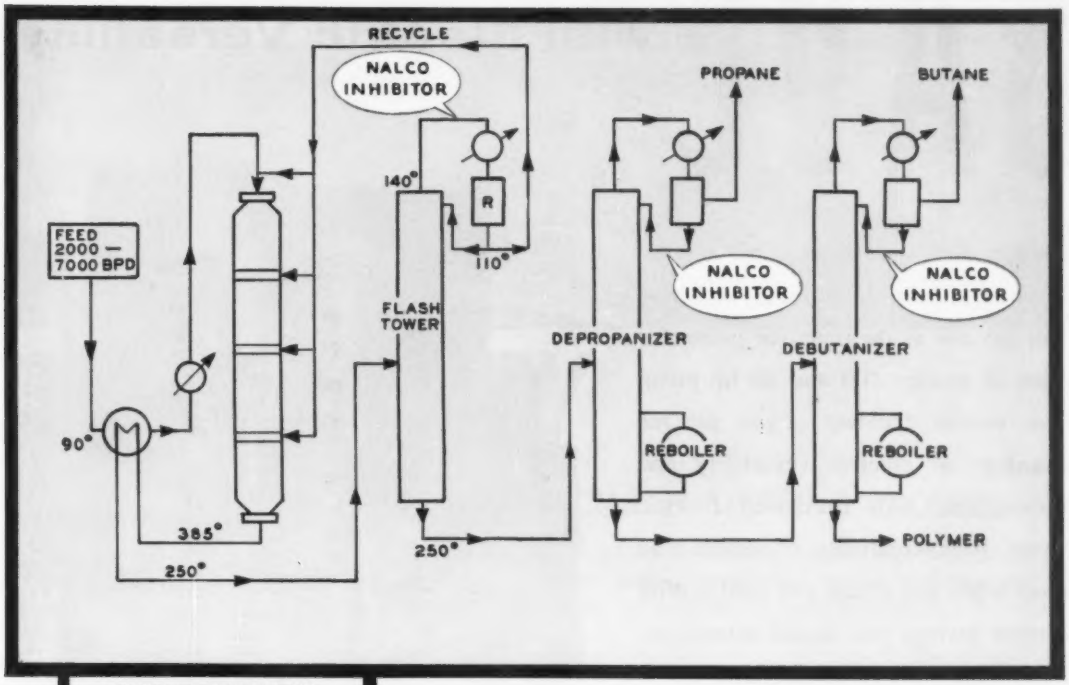
DARLING VALVES

For more data on advertised products, use Readers' Service Cards, last page.

Nalco INHIBITORS

STOPPED CORROSION and FOULING

in this CATALYTIC POLYMERIZATION UNIT



THE PROBLEM

1. *Corrosion* of the steel tube bundles of the flash tower overhead condenser with accumulator water pH of 4.5 or below.
2. *Serious fouling* of screen trays in the depropanizer and debutanizer on normal six-month run.

THE TREATMENT

Nalco Inhibitor fed to the overhead of the flash tower, and to the reflux of the depropanizer and debutanizer towers.

THE RESULTS

1. Iron content of accumulator water reduced from .75 pounds per day to .04 pounds per day.
2. No deposits in screen trays after six-month run.

CONSIDER further the economy of dosage . . . 10 ppm to flash tower, and 10 ppm to depropanizer and debutanizer. And bear in mind that this was no isolated success story. The same advantages—less downtime, better thruput *and* effective protection for costly equipment—can be brought to your refinery by the use of Nalco Corrosion and Fouling Inhibitors. Ask your Nalco Representative or write direct.

National Aluminate Corporation is now

NALCO CHEMICAL COMPANY

6529 West 66th Place • Chicago 38, Illinois

Subsidiaries in England, Italy, Mexico, Spain, Venezuela and West Germany

In Canada—Alchem Limited, Burlington, Ontario

THE *Nalco*® SYSTEM... *Serving Industry through Practical Applied Science*

Nalco CHEMICALS

For more data on advertised products, use Readers' Service Cards, last page.

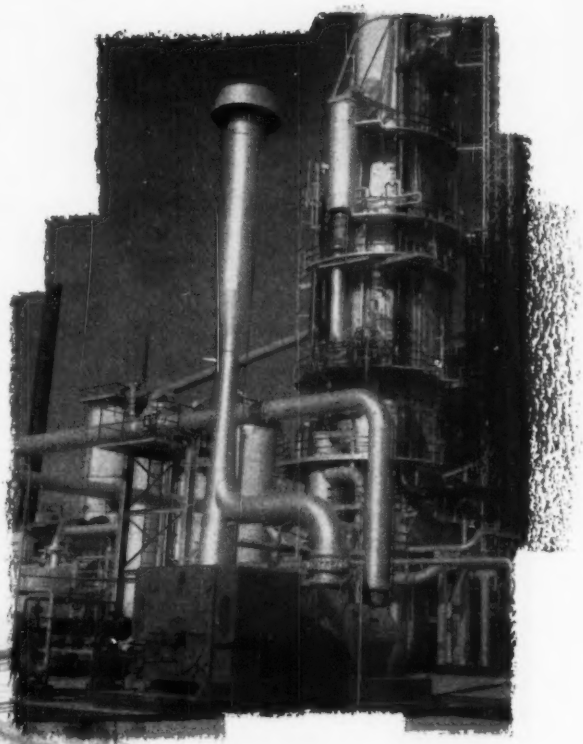
SAVE manpower

SAVE money

SAVE maintenance

SAVE with Electric Versatility

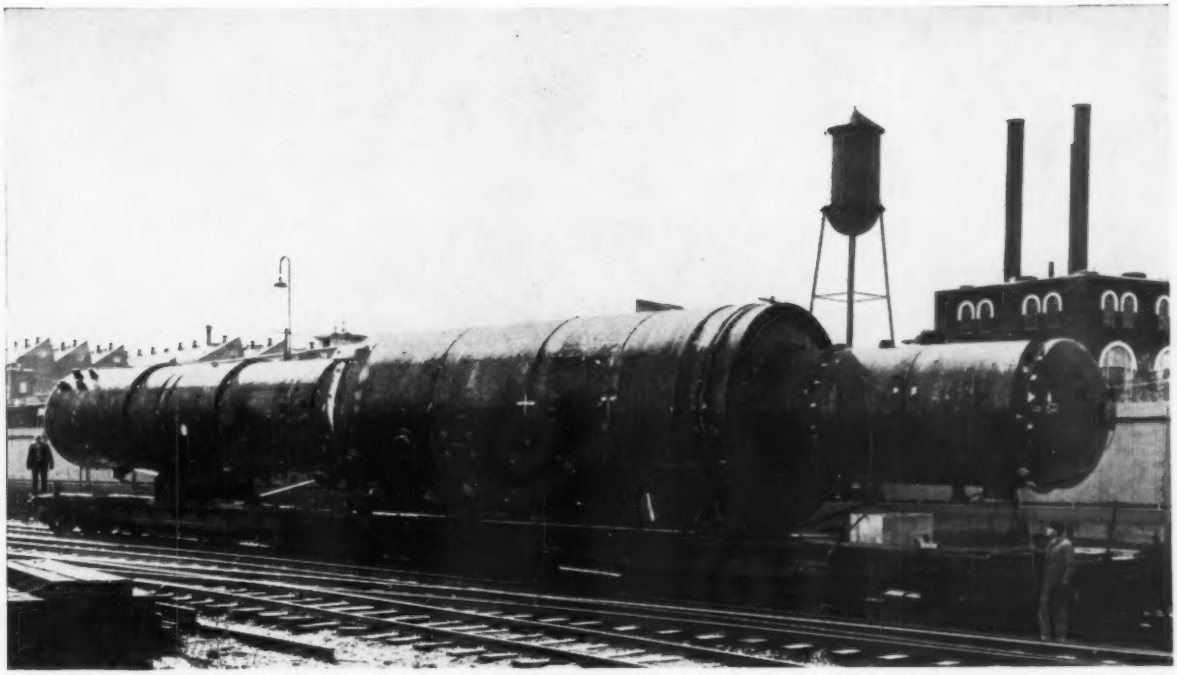
Whether you need dependable electric power for a giant 2,000 hp blower drive (like the one at the right) or power for a line of smaller 100 and 40 hp pump drive motors (below) . . . you get the advantage of electric versatility and dependability with Purchased Electric Power. High continuity of service and power when and where you need it offer multiple savings you should investigate. Call your nearest Utility Electric Power Company for details or write us.



PEPA

Purchased Electric Power . . .
saves money, manpower, maintenance and serves you better automatically

Petroleum Electric Power Association
P.O. BOX 35006, DALLAS 35, TEXAS



VERSATILITY

SOLVES PROBLEMS IN SHIPPING PROCEDURE

The variety of large-size work which Sun Ship's shops produce is matched by a variety of equally important shipping problems. Sun's facilities for shipping by water (overseas, coastal, or inland)—directly from our plant, are often the most economical available, and when large pressure vessels, such as those shown here, are scheduled for overseas shipment, direct, plant-to-ship loading saves additional time and expense.

Inland customers benefit from our ability to pre-check clearances and schedule shipments by rail or truck before production ever begins, so that delivery on schedule . . . on budget . . . is assured. Thus VERSATILITY . . . which has been made a "standard procedure" through Sun's experience . . . is extended through one more avenue . . . Shipping Procedure.

For more data on advertised products, use Readers' Service Cards, last page.

SAVE
manpower

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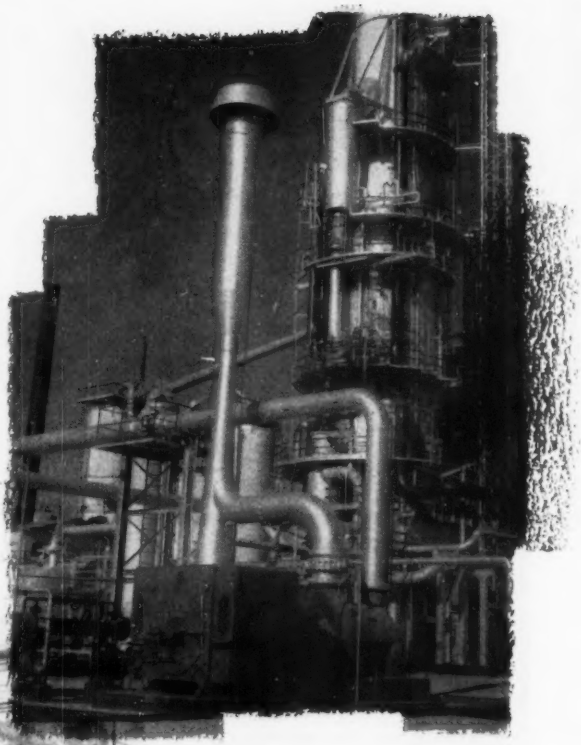

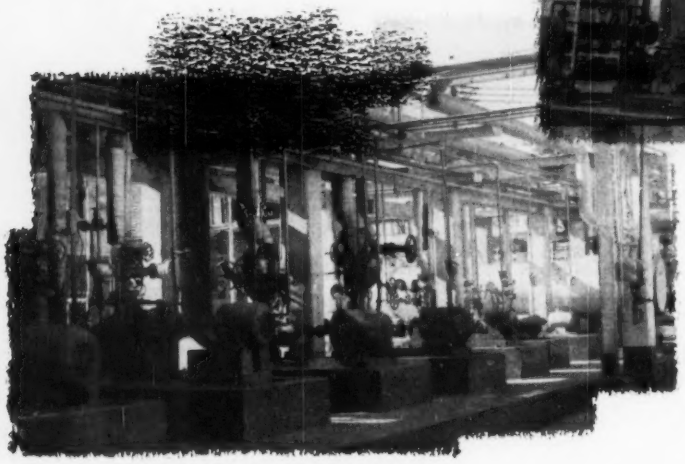

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P.O. BOX 35006, DALLAS 35, TEXAS

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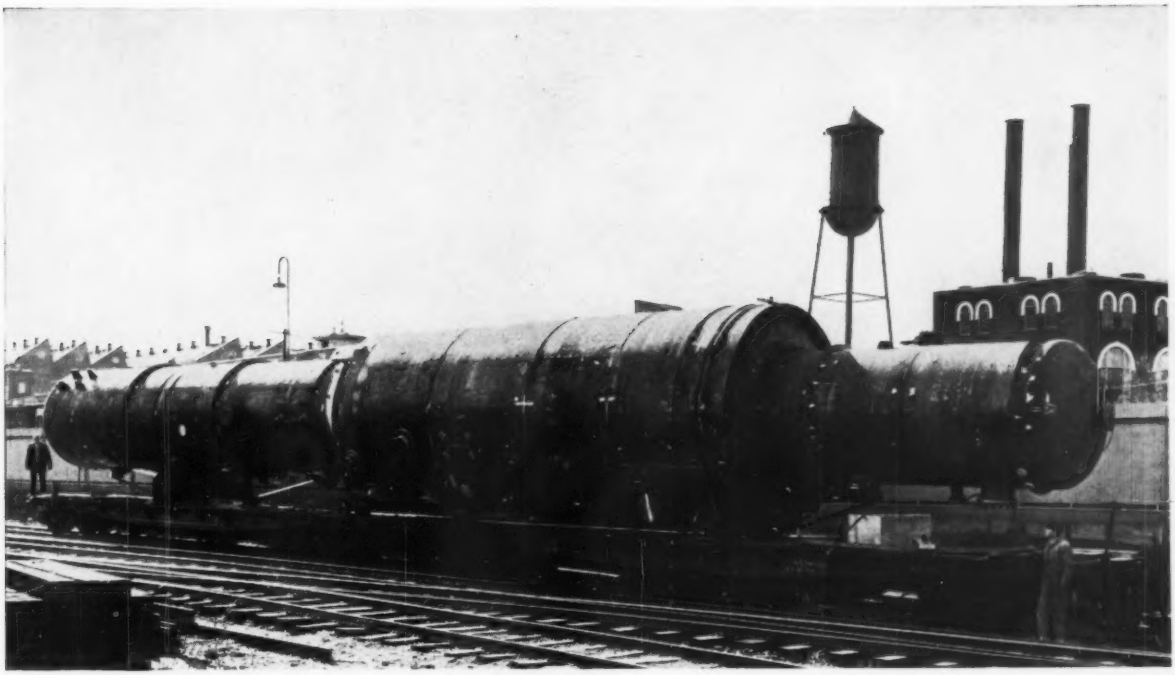

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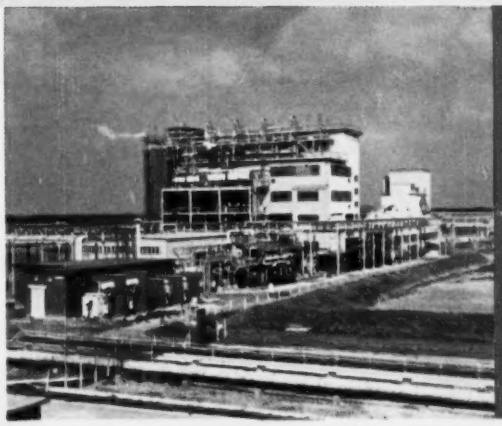
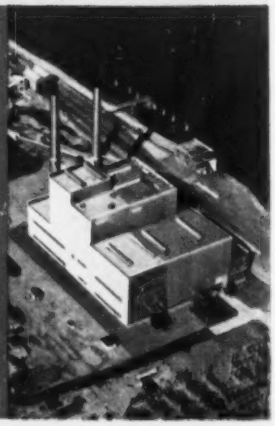
For more data on advertised products, use Readers' Service Cards, last page.

THE MUSCLES OF TOMORROW

Will be produced in plants Stone & Webster builds today



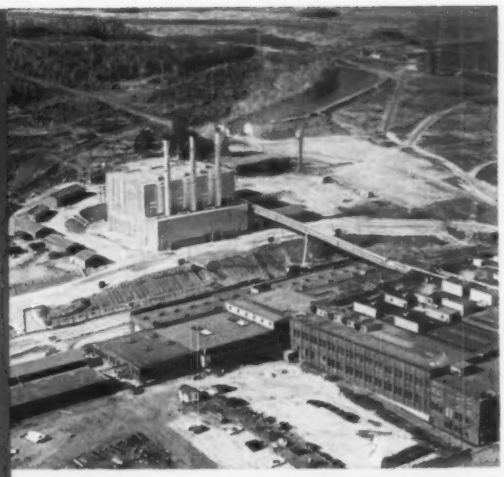


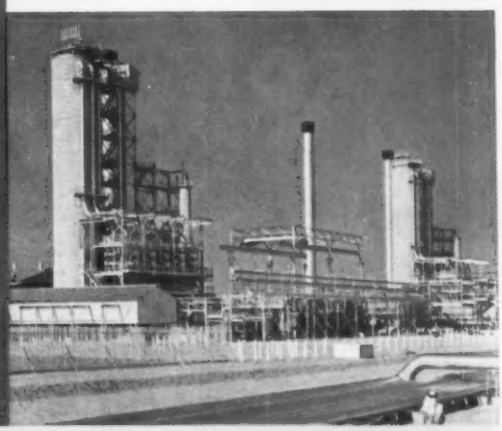
STONE & WEBSTER
ENGINEERING CORPORATION
A Subsidiary of Stone & Webster, Inc.

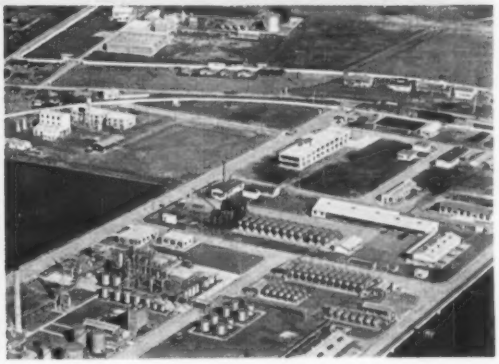
Atomic, hydroelectric and steam power, new plastics formed by molecular chemistry, new products from molded pulp and paper . . . these are some of the materials and forces that are reshaping our universe. These very same materials and forces are being produced today in plants designed and constructed by Stone & Webster.

Building today for tomorrow's needs has been Stone & Webster's objective for 70 years. The plants we build today must compete profitably with tomorrow's plants. This can only be achieved by reducing construction and operating costs . . . by scrupulously respecting client budgets and schedules.

If your company is contemplating expansion or actively planning new facilities, let us demonstrate how Stone & Webster's experience can add to your future profits. Call or write our nearest office.







NEW YORK • BOSTON • CHICAGO
PITTSBURGH • HOUSTON • SAN FRANCISCO
LOS ANGELES • SEATTLE • TORONTO

ROYAL PRECISION

LGP-30

Twice the capacity of any computer in its class...easiest to program in basic machine language...lowest in cost

With the compact, powerful LGP-30, you can obtain peak operating efficiency through on-site linear programming...can save substantially on every barrel produced by faster, simpler selection of (1) optimum-level production, sale and purchase of gasoline, butane, naphtha etc.; (2) severity level of the catalytic reformer; (3) tetraethyl lead content.

Because the LGP-30 is mobile, you can now have high-speed electronic computation *wherever you need it*. Operating from any convenient wall outlet, the self-cooled LGP-30 gives you memory (4096 words) and capacity comparable to computers many times its size and cost.

The lowest-priced complete computer you can buy, the LGP-30 has been so simplified that even non-technical personnel quickly grasp its operation. A library of sub-routines and programs is maintained – as well as an active users organization. Service facilities are available coast-to-coast.

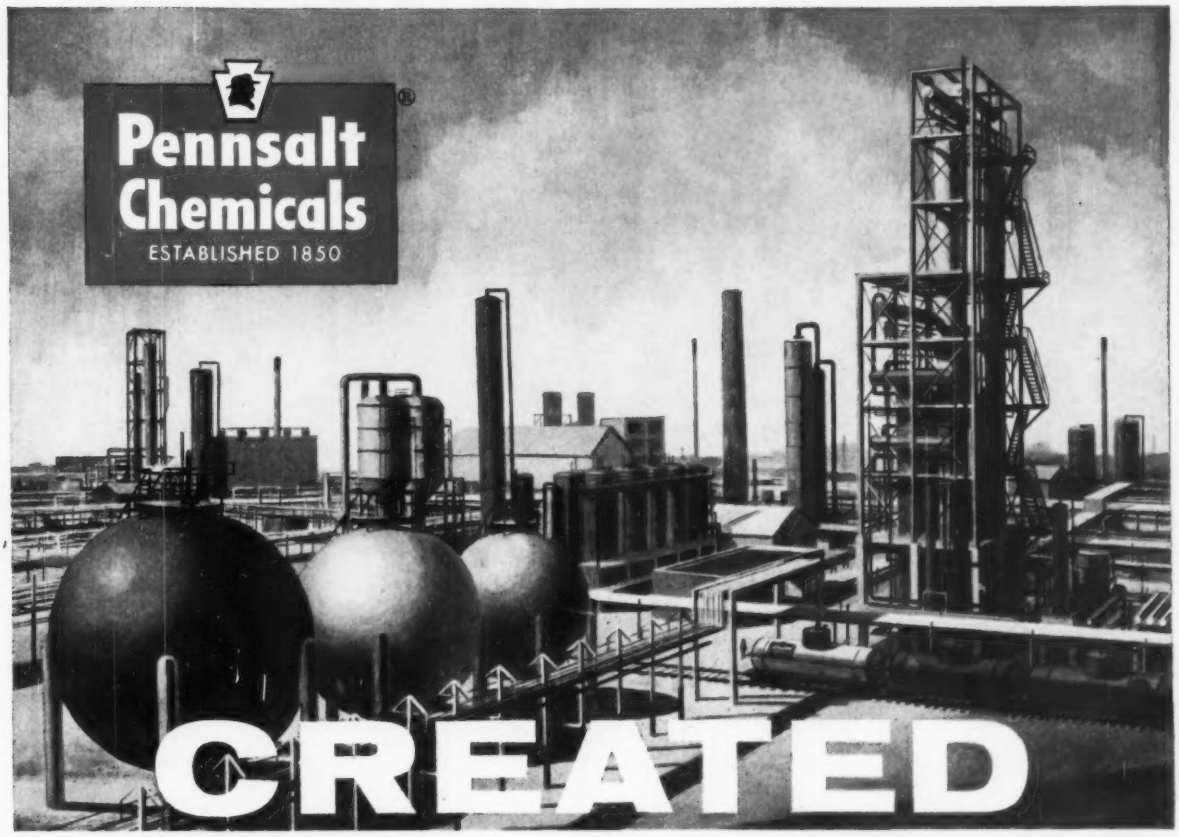
Gives you optimum level efficiency in production, sales, purchase!

Other important jobs now being assigned to the LGP-30 in numerous petroleum installations include the following: pipeline problems; mass spectrometer calculations; analysis of oil field production; flash point calculations; pumping and batching scheduling; correlation of seismic records; reservoir engineering studies; well-logging interpretations.

ROYAL McBEE

data processing division

For further information and specifications, write Royal McBee Corporation, Data Processing Division, Port Chester, N.Y.



in only 8 months at 10 per cent under budget

10% UNDER BUDGET—Pennsalt Chemicals Corporation's new Methylamines plant was completed by Catalytic, Engineers—Constructors, at a figure ten per cent under the original estimated cost.

AHEAD OF SCHEDULE—The Methylamines plant was completed and ready for start-up in only eight months after the start of engineering. This "On-Time" completion was in advance of the requirements of Pennsalt Chemicals Corporation.

UNDIVIDED RESPONSIBILITY—Catalytic's control and coordination of all phases of this project and close cooperation with the client were prime factors in the successful completion. This Methylamines plant again proved Catalytic's ability to render all client services "On-Time, On-Budget".

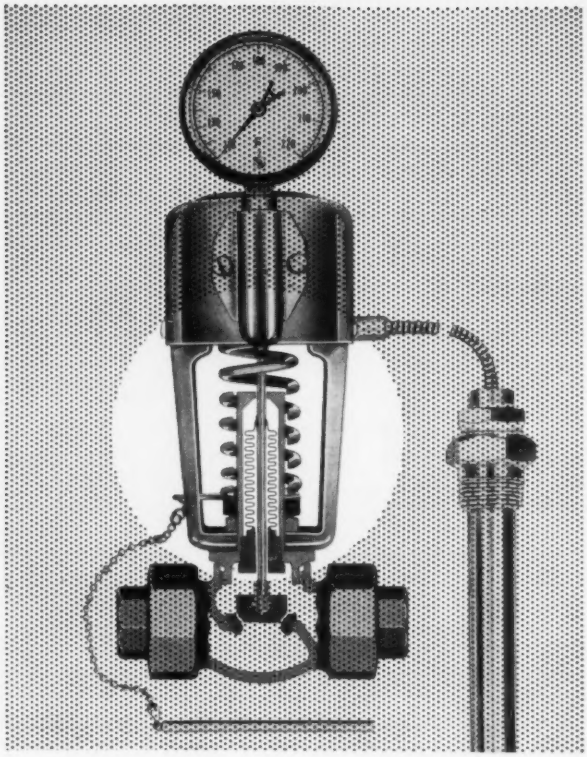
CATALYTIC
CONSTRUCTION COMPANY

Philadelphia 2, Pa.
New York, N. Y.
Baton Rouge, La.
Toledo, O.
Tulsa, Okla.
In Canada: Catalytic Construction of Canada, Limited; Sarnia, Ontario; Toronto, Ontario; Montreal, Quebec.

Catalytic *On-Time . . . On-Budget* Services for the metallurgical, chemical, petrochemical and oil refining industries: Project Analysis; Process Development; Process Design; Economic Studies; Engineering; Procurement; Construction.

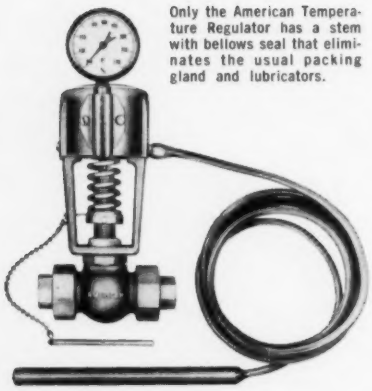
For more data on advertised products, use Readers' Service Cards, last page.

Temperature Regulation with Corrective Action within 1/10 of a degree



A friction-free bellows seals off the valve stem on the new American Temperature Regulator. Result: no stem binding to retard valve action, fastest possible temperature response.

The bellows seal makes practical a friction-free, nonleaking packless valve that needs no lubrication. This innovation plus an extra-long, preflexed adjusting spring marks the new American Temperature Regulator as the fastest acting, most stable available. Corrective action starts at less than 1/10 degree change at the bulb. And the adjusting spring allows unusual latitude in temperature settings.



Only the American Temperature Regulator has a stem with bellows seal that eliminates the usual packing gland and lubricators.

Compact design permits installation in "tight" locations. The dial thermometer on the indicating-type regulator can be positioned for easiest reading regardless of piping arrangements. Standardized parts and unitized assembly mean low initial cost. Maximum feasible use of stainless steel and a minimum number of components eliminate maintenance problems.

Get the best in economy, accurate temperature regulation, and dependability. Choose American Temperature Regulators. *Sizes:* ½" to 1½". *Temperature Ranges:* As low as minus 15°F. to 50°F.—as high as 240F°. to 350°F. *Valve:* Bronze body, stainless steel seat and disc. *Ask for Bulletin 114A.*

Phone your industrial supply distributor for counsel, service and prompt delivery from his local stocks.

MAXWELL MANNING M&M & MOORE, INC. TRADE MARK

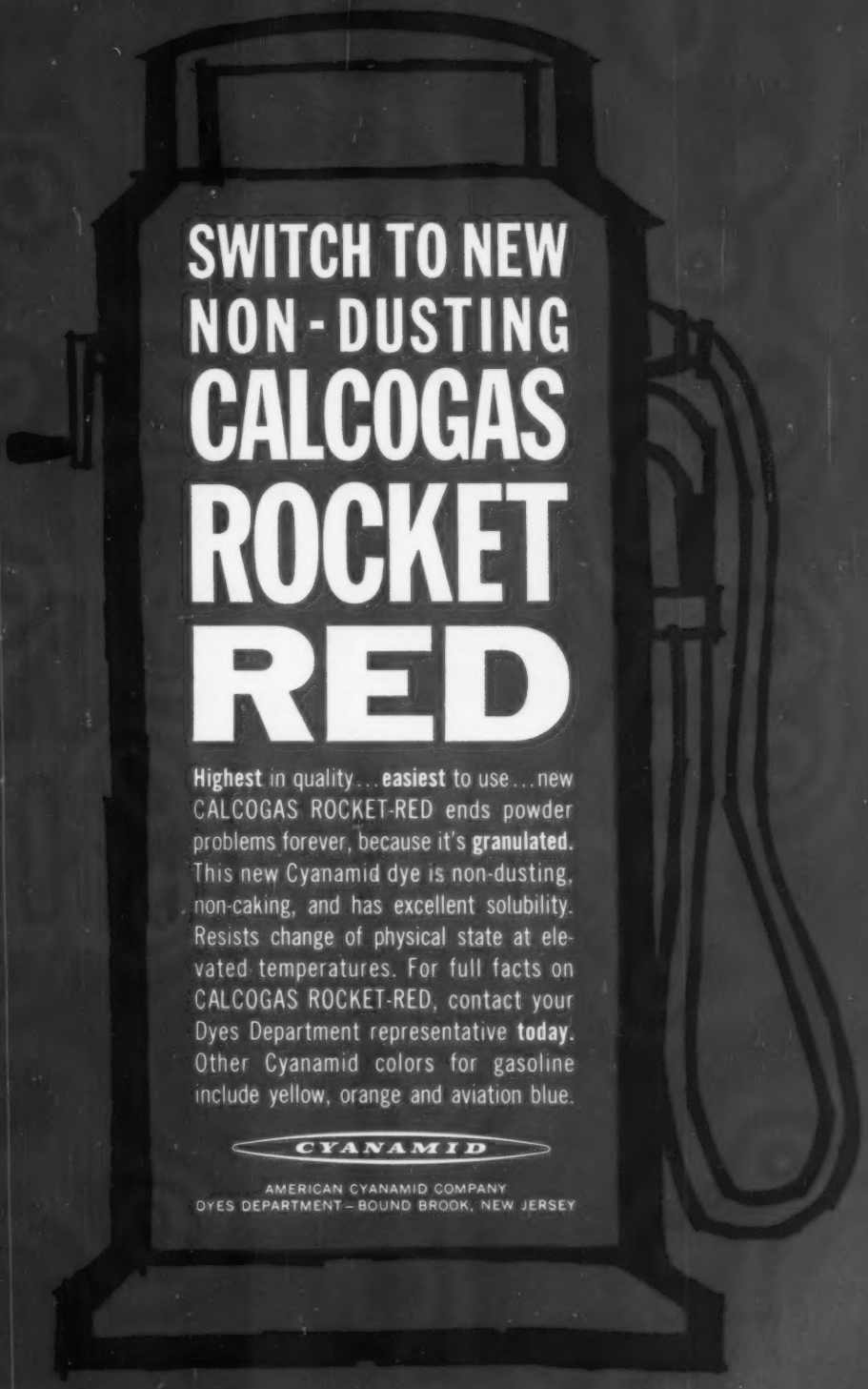
AMERICAN TEMPERATURE REGULATORS

A product of

MANNING, MAXWELL & MOORE, INC.

Consolidated Ashcroft Hancock Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

For more data on advertised products, use Readers' Service Cards, last page.



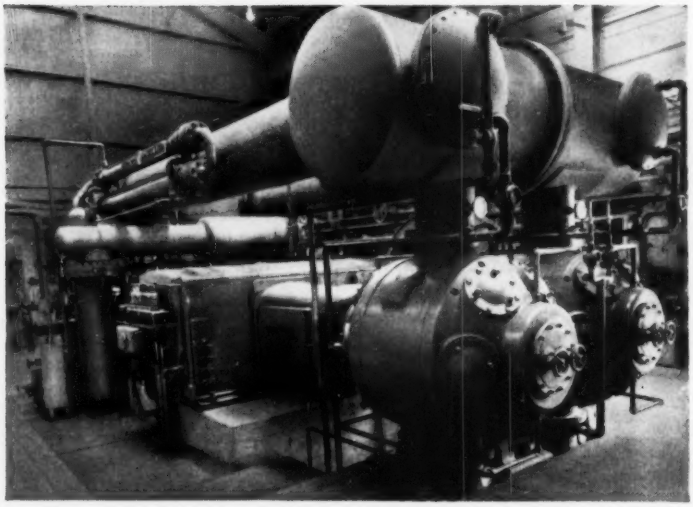
SWITCH TO NEW NON-DUSTING CALCOGAS ROCKET RED

Highest in quality... **easiest** to use... new CALCOGAS ROCKET-RED ends powder problems forever, because it's **granulated.** This new Cyanamid dye is non-dusting, non-caking, and has excellent solubility. Resists change of physical state at elevated temperatures. For full facts on CALCOGAS ROCKET-RED, contact your Dyes Department representative **today.** Other Cyanamid colors for gasoline include yellow, orange and aviation blue.

CYANAMID

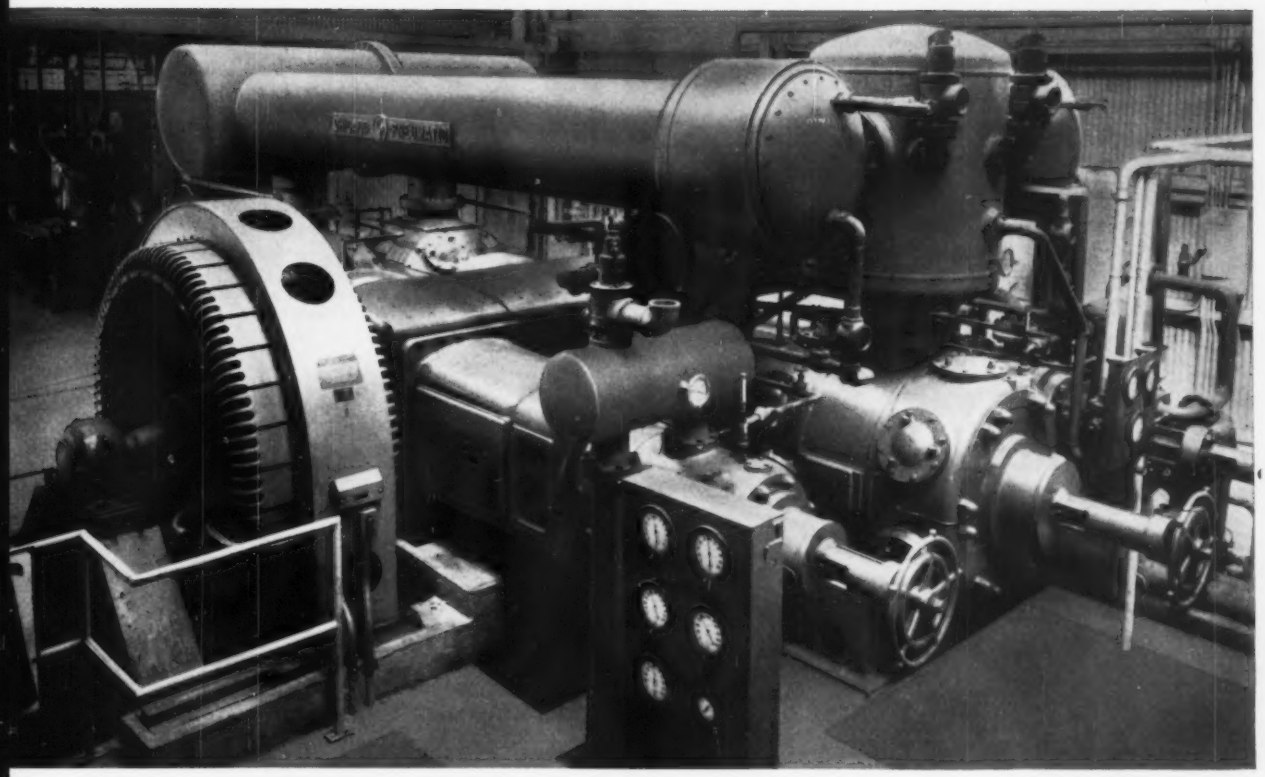
AMERICAN CYANAMID COMPANY
DYES DEPARTMENT – BOUND BROOK, NEW JERSEY

CLASS WORKHORSE



Two views of a 2500hp, five-throw, five-stage Class FE Compressor installed in a large steel plant

For more data on advertised products, use Readers' Service Cards, last page.



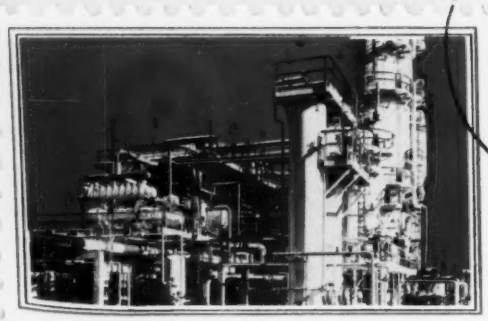
FE COMPRESSORS FOR AIR LIQUEFACTION

Class FE horizontal, balanced-opposed compressors are doing an impressive job in the production of oxygen and in many other processes which demand compressors that take high pressures and heavy duty service in their stride. The "FE" is only one of many CP designs for such requirements. Horsepowers to 5000; pressures up to 15,000 pounds. Write for detailed specifications.

Chicago Pneumatic 8 East 44th Street, New York 17, N. Y.

AIR AND GAS COMPRESSORS • VACUUM PUMPS • PNEUMATIC TOOLS • ELECTRIC TOOLS • DIESEL ENGINES • ROCK DRILLS • HYDRAULIC TOOLS

For more data on advertised products, use Readers' Service Cards, last page.



ITALY — 10,000 metric ton/yr phthalic anhydride plant now being handled for ACNA in Cengio.

Around the world, engineering projects of note bear the Badger Stamp

CANADA — tar distillation plant for Dominion Tar and Chemical Company, Limited, Hamilton, Ontario, Canada.

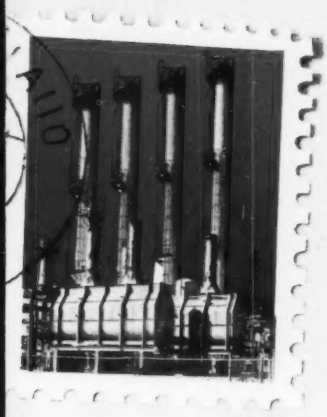
Badger affiliates and sales and field offices approach world-wide status. Through these well-established and rapidly expanding facilities, Badger is currently engineering and constructing more than twenty-five major projects for local, regional and international clients in the petroleum, chemical and nuclear energy industries.

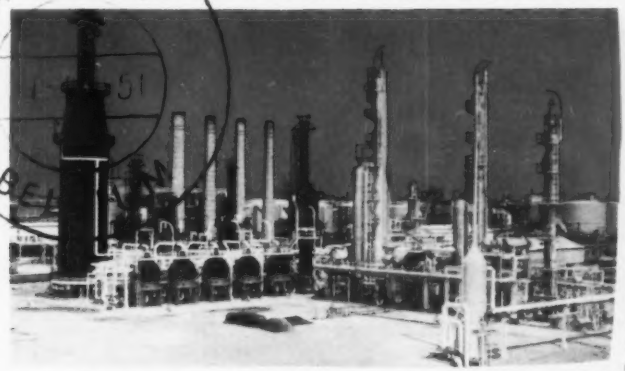
Considering a plant project in this country? . . . or abroad? Call on Badger for proven ability and experience available on-the-spot . . . anywhere. For more information write or call today. Badger Manufacturing Company, 363 Third St., Cambridge 42, Massachusetts.

built by **BADGER**

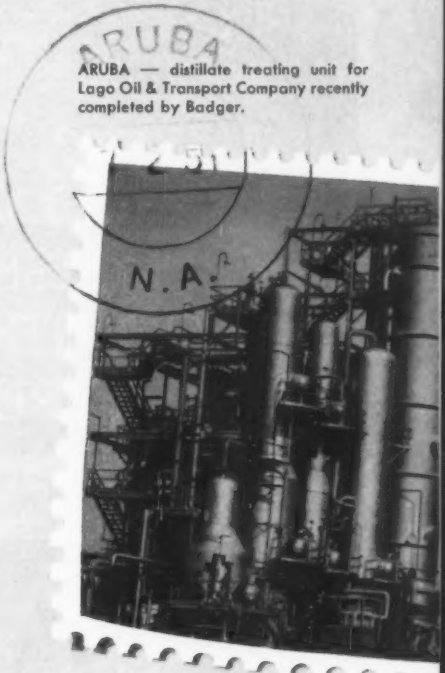
INTERNATIONAL DESIGNERS • ENGINEERS • CONSTRUCTORS

THE BADGER COMPANIES: BADGER MANUFACTURING COMPANY - CAMBRIDGE, NEW YORK, HOUSTON • CANADIAN BADGER COMPANY LTD. THE HAGUE, HOLLAND • BADGER LIMITED - LONDON, ENGLAND • BADGER (BELGIUM) S.A. - BRUSSELS, BELGIUM

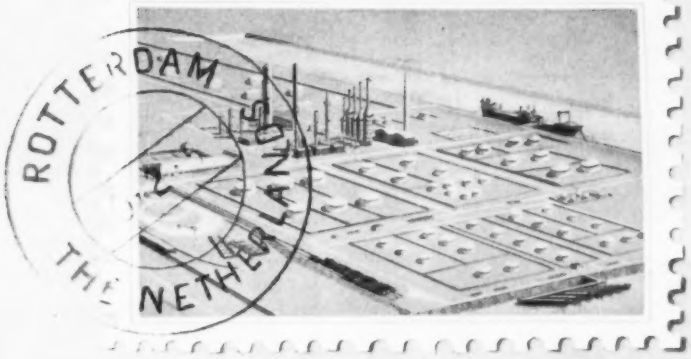




BELGIUM — Powerformer-Hydrofiner and miscellaneous offsite facilities recently completed for Esso Standard Refinery S.A. in Antwerp.



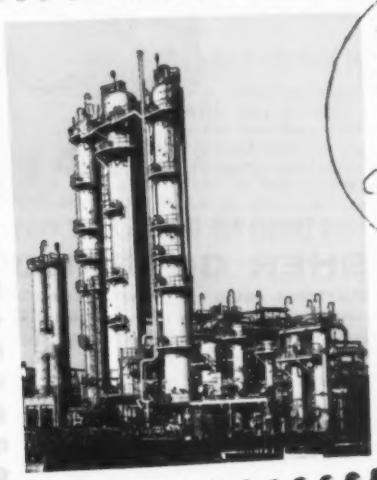
ARUBA — distillate treating unit for Lago Oil & Transport Company recently completed by Badger.



THE NETHERLANDS — complete 100,000 bpsd "grass-roots" refinery under construction for Esso-Nederland N.V. in Rotterdam.

TAIWAN — 600 bpsd sulfuric acid alkylation plant now under construction for Chinese Petroleum Corporation in Kaohsiung.

UNITED STATES — benzene unit engineered for Gulf Coast refiner. Produces 24 million gallons of purified benzene annually.



ORONTO, ONTARIO, CANADA • BADGER N.V. -

ADGER (FRANCE) S. à R.L. - PARIS, FRANCE

POWER
SPEED
COMPACTNESS

Fisher-Continental Type 480 will give you all 3 on your next

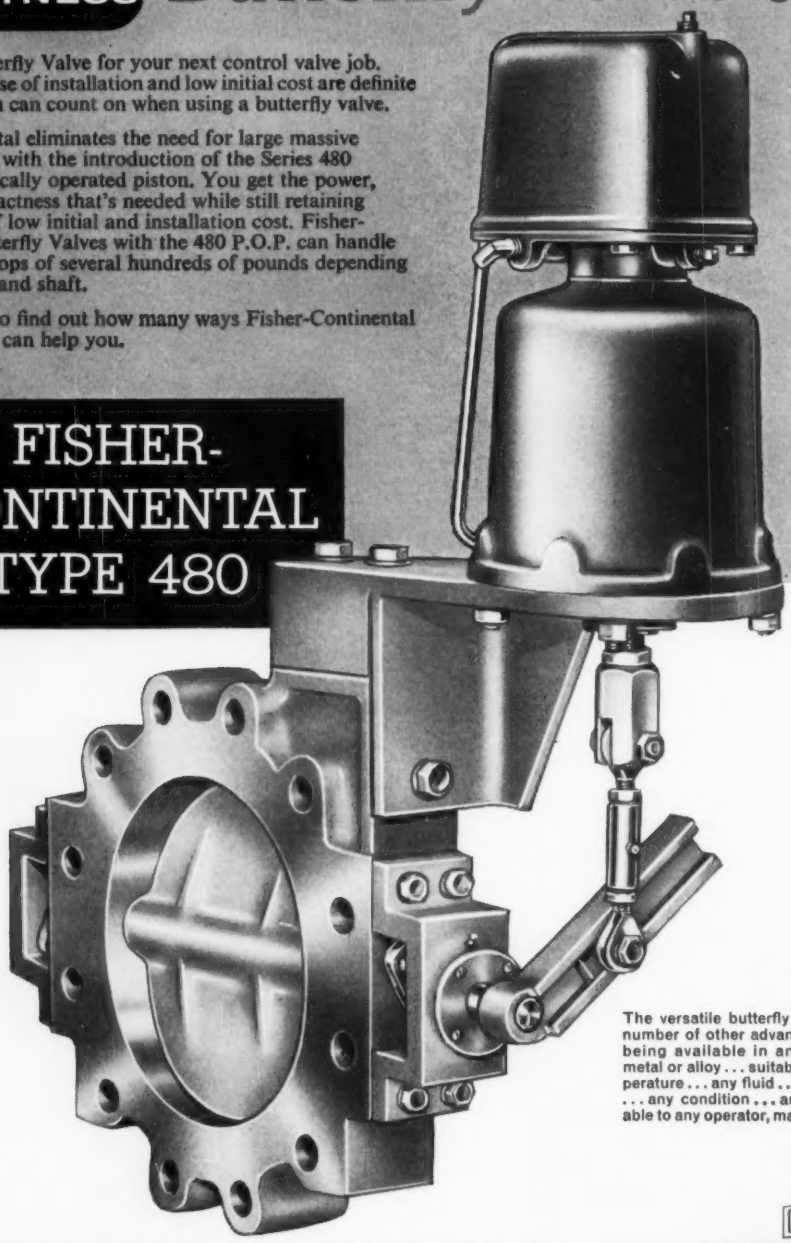
Butterfly Valve Job

Consider a Butterfly Valve for your next control valve job. Compactness, ease of installation and low initial cost are definite plus features you can count on when using a butterfly valve.

Fisher-Continental eliminates the need for large massive power actuators with the introduction of the Series 480 P.O.P. pneumatically operated piston. You get the power, speed and compactness that's needed while still retaining the advantage of low initial and installation cost. Fisher-Continental Butterfly Valves with the 480 P.O.P. can handle high pressure drops of several hundreds of pounds depending on size of body and shaft.

It will pay you to find out how many ways Fisher-Continental Butterfly Valves can help you.

FISHER-
CONTINENTAL
TYPE 480



The versatile butterfly valve offers a number of other advantages such as being available in any size... any metal or alloy... suitable for any temperature... any fluid... any pressure ... any condition... and it is adaptable to any operator, manual or power.

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD... CHANCES ARE IT'S CONTROLLED BY...

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT CO., CORAOPOLIS, PENNSYLVANIA

CONTINENTAL

FISHER® Controls

SINCE 1880

PUMPAGE

Goulds news about pumps for process industries

Idea from a cosmetic bottle

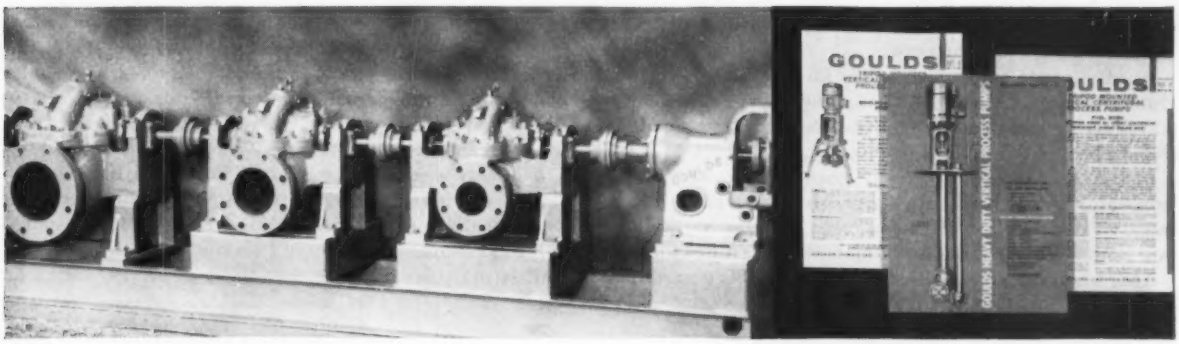
Cold wave lotion made from Evans Chemetics' thioglycolic acid comes to consumers in a bottle. A *glass* bottle. That set Evans to thinking: if *glass* prevents contamination in packaging, why can't it do the same job in *processing?* So they installed a Goulds-Pfaudler *glassed* pump. In it, glass is permanently fused to metal at every surface that contacts the pumpage. Result? Where expensive alloys were required to prevent contamination during processing, now smooth *glass* does the job . . . *better!* Maintenance and replacement problems ended too—for a full year after installation! Write for Bulletin 725.2.

Largest and smallest

The man dwarfed by the giant pump is a Goulds Application Engineer. Look closer. He's holding another pump, small enough and light enough to be held in one hand! His assignment: select the right pump for *your* specific need from all the pumps that fall within the range of Goulds' largest and smallest pumps. For instance—want to move a *lot* of liquid *fast?* That big job does it at *40,000 GPM!* Need a small, stainless steel pump that you can use 24 hours a day for chemical circulating or transfer work? Get as little as 1 GPM with the little pump. Cut pumping costs with the *right* pump for your job.

Pump with a built-in "steam bath"

When fat is a problem—try a steam bath! The steam bath we're speaking of keeps fats, wax, paraffin and other low-melting point solids *fluid* in your pumping system. It's "built-in" on the Goulds Fig. 3715 chemical pump to maintain high process temperatures—right at the pump. A steel steam jacket of full casing diameter keeps *all* the liquid in the pump hot. Can be furnished with new, or added to existing, pumps. You pump low melting point fluids or saturated salt solutions without "freezing"—to reduce down time in your operation. Write for Bulletin 725D17.



Tandem-mounted pump idea

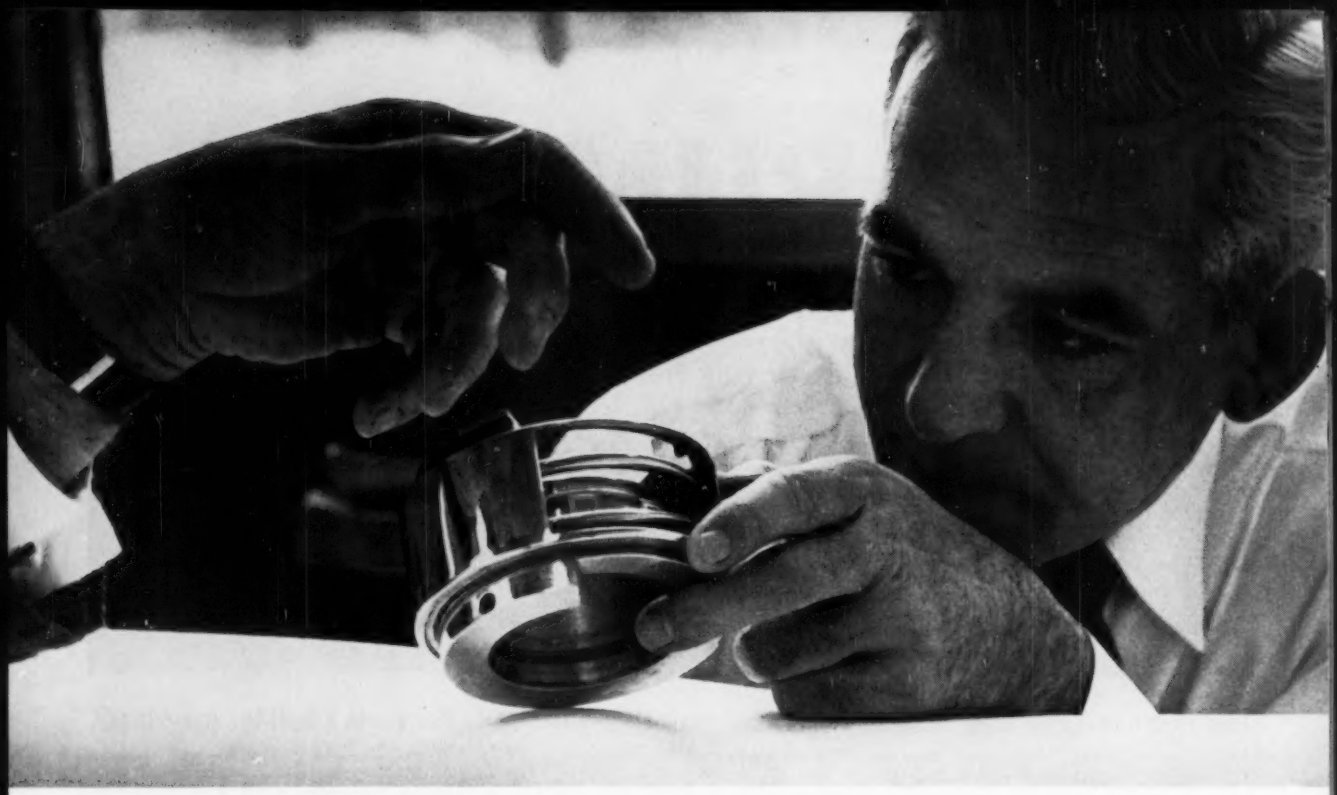
Here's where it might pay you to put all your eggs in a single basket! One oil refiner set up four Goulds pumps *in tandem*, powered the whole works with one steam turbine. Advantages? The combined total horsepower allowed selection of a more efficient large turbine with reduced steam consumption—plus eliminating 3 turbines, bases and foundations. The two Goulds Fig. 3405 pumps in the center handle rich oil at 300 and 375 GPM respectively, with heads of 211 feet. At the left is a Goulds Fig. 3405 that pumps 600 GPM of lean oil at 248 ft. head. Pump on the right is a Fig. 3755 for supplying still reflux at 155 GPM and a head of 149 feet. All pumps and the turbine are mounted on a common steel base.

News about vertical process pumps!

Here's a complete rundown on what's new with heavy-duty vertical process pumps for handling corrosive liquids in the chemical process and allied industries. In many applications in the process field, the use of vertical pumps for transfer or other services offers many advantages. Advanced design provides for wet pit, dry pit and tripod-mounted pumps with maximum interchangeability of parts. These booklets list them all—and they're yours *free.* Just send to Goulds for your copy. Write Goulds Pumps, Inc., Dept. PR-69, Seneca Falls, New York.

GOULDS GP PUMPS

For more data on advertised products, use Readers' Service Cards, last page.



Cut mixer maintenance cost as much as 60%

. . . specify LIGHTNIN Mixers with this leakproof seal

This mechanical seal can save you up to 60% of what you'd expect to spend on annual upkeep of a side-entering mixer on a big blending tank.

It *never* needs adjustment—runs for years without attention. It eliminates all the costly maintenance of a packed stuffing box.

At the same time, it positively stops troublesome drip, drip, drip—prevents waste of product and gives you clean, safe housekeeping around the tank.

And, when the seal finally does wear out, it's easy to replace—just a simple cartridge unit. One man can do the job easily and quickly, even with a full head of liquid in the tank.

There are no loose seal parts you have to assemble—no delicate adjustments to make. The cartridge is easy to stock as a spare. Or you can get a new one from MIXCO in a hurry when you need it. The seal is made in all sizes, and in materials to suit the simplest or toughest mixing conditions.

Biggest surprise of all is the price. A seal-equipped LIGHTNIN Mixer costs only a few dollars more than one equipped with a packed stuffing box.

Refiners everywhere are saving thousands of dollars yearly on mixer maintenance with this exclusive LIGHTNIN Mixer feature. To learn how inexpensively *you* can use it to build low-cost upkeep into your big blending tanks, call in your LIGHTNIN Mixer representative today. He's listed in Refinery Catalog. Or write us direct.

For simplest possible maintenance, you can get LIGHTNIN Side Entering Mixers in a wide choice of corrosion-resistant materials, with gear drive or V-belt drive, and with mechanical seals or stuffing boxes to meet every service condition.

"Lightnin® Mixers"

MIXCO fluid mixing specialists

☐ Send us the cost-cutting facts on LIGHTNIN Rotary Mechanical Seals—Bulletin B-111. We'd also like catalog information on these LIGHTNIN Mixers:

☐ Side entering: 1 to 25 HP (B-104)

☐ Top or bottom entering; turbine, paddle, and propeller types: 1 to 500 HP (B-102)

☐ Top entering propeller types: ¼ to 3 HP (B-103)

☐ Portable: ⅛ to 3 HP (B-108)

☐ Laboratory and small-batch production types (B-112)

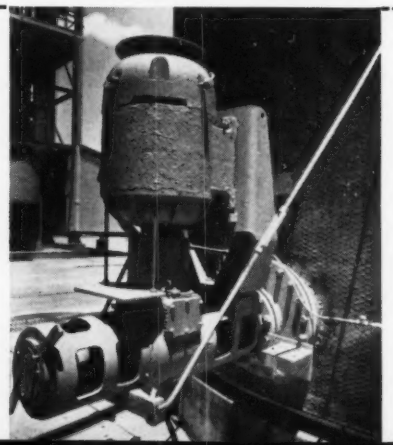
☐ Condensed catalog showing all types (B-109)

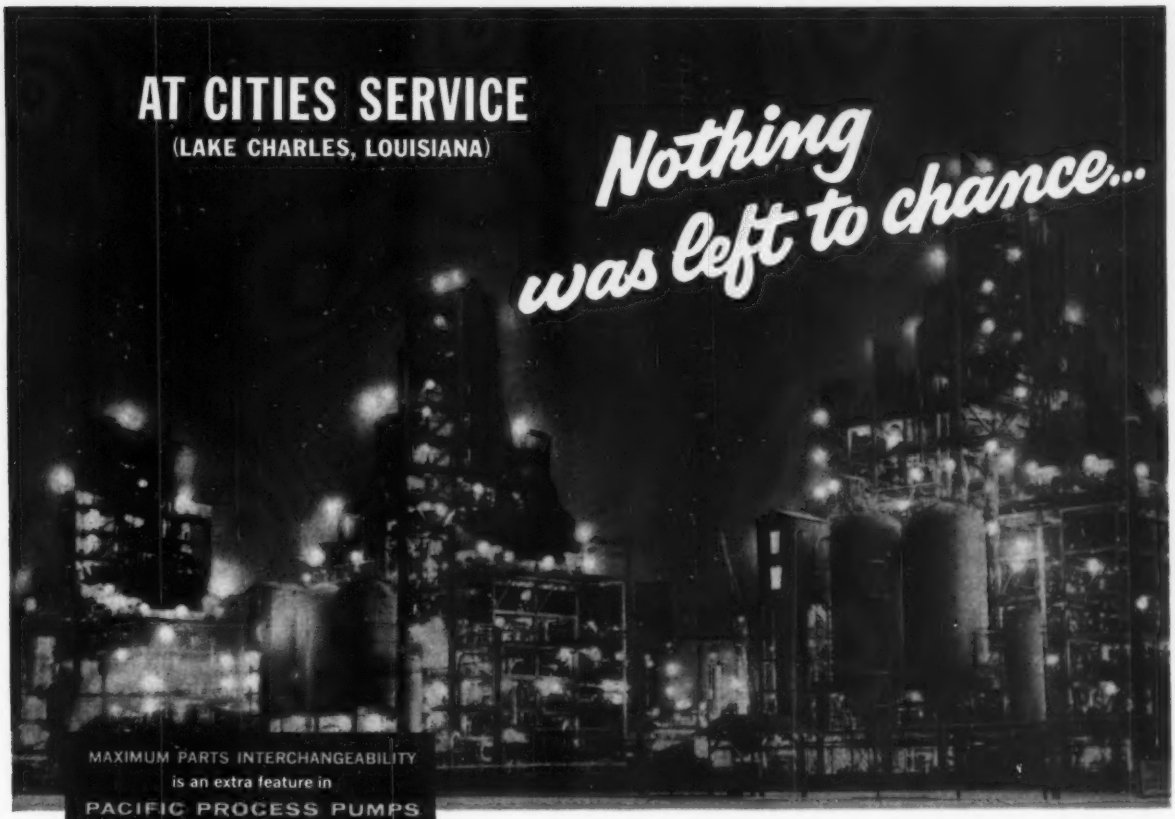
☐ Data sheet for figuring mixer requirements (B-107)

Check, clip and mail with your name, title, company address to:

MIXING EQUIPMENT Co., Inc., 164-f Mt. Read Blvd., Rochester 3, N.Y.

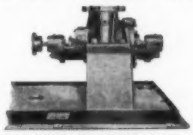
In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Ave., Toronto 19, Ont.



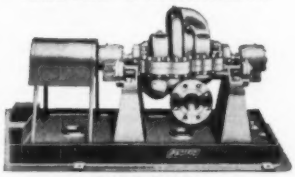


MAXIMUM PARTS INTERCHANGEABILITY
is an extra feature in
PACIFIC PROCESS PUMPS

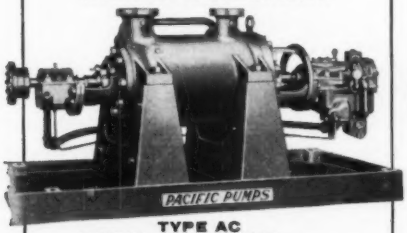
TYPE SVC
To 850°F.—25 to 3200 GPM
To 600 PSIG—To 650 DIFF. HD. FT.



TYPE HVC
To 850°F.—600 to 4500 GPM
To 600 PSIG—To 1000 DIFF. HD. FT.



TYPE RHC
To 500°F.—50 to 3000 GPM
To 700 PSIG—To 1300 DIFF. HD. FT.



TYPE AC
To 850°F.—100 to 2500 GPM
To 1000 PSIG—To 2600 DIFF. HD. FT.

Practically 100% PACIFIC

process pumps are in service at:

CITIES SERVICE REFINERY
PETRO-CHEMICAL, INC.
CIT-CON, INC.

The three fluid catalytic crackers illustrated have established new records for continuous operation since going on stream. Under the most demanding service conditions, all three units came through remarkably. Number two unit operated for 1058 consecutive 24-hour days only to be outdone by its sister unit with a record of 1065 days continuous operation. We feel that the 100% Pacific installation (including slurry pumps) contributed to making these run-records possible.

Elsewhere throughout Cities Service, P.C.I. and Cit-Con operations, Pacific process pumps are delivering equally dependable 'round-the-clock service...convincing evidence that "nothing was left to chance."

Write for Complete Line Bulletin 1C plus individual bulletins for pumps illustrated in panel.

PACIFIC

PACIFIC PUMPS INC
A Division of Dresser Industries, Inc.
HUNTINGTON PARK, CALIFORNIA

CP-20

For more data on advertised products, use Readers' Service Cards, last page.

HELPFUL WATER CONDITIONING DATA FROM BETZ

HOW CORROSION ATTACKS

■ Boiler, cooling and process water systems are constantly plagued by corrosion. This article tells how and why.

CORROSION can be defined as the destruction of a metal by chemical or electrochemical reaction by its environment. In the corrosion of ferrous metals in contact with moisture, reversion of the metal to the oxide form takes place. The driving force or the tendency to corrode is electrochemical. However, the rate at which corrosion proceeds is largely dependent on the resistance to continued attack by the products of the corrosion reaction.

In industrial water systems, the principal factors influencing corrosion of ferrous metals are the water characteristics, temperature, rate of flow and the contact of dissimilar metals. The chief variables controlling the characteristics of a water are its dissolved oxygen content, carbon dioxide concentration, pH and dissolved solids. Other factors are involved, of course, such as the possible presence of free mineral acid, hydrogen sulfide, sulfur dioxide, etc. In addition, certain bacteria may be a factor.

Dissolved Oxygen

The presence of oxygen is usually essential for serious corrosion to take place in natural waters. Dissolved oxygen will greatly accelerate corrosion in acid, neutral, or slightly alkaline waters.

The corrosion of iron in pure water in the presence of oxygen may be expressed in a simplified way by the following equations:

$$\text{(a)}\quad \underset{\text{iron metal}}{Fe} + \underset{\text{hydrogen ion}}{2H^+} \rightleftarrows \underset{\text{ferrous ion}}{Fe^{++}} + \underset{\text{hydrogen atoms}}{2H^\circ}$$

This is the typical primary reaction, in which iron enters the solution as ferrous ions, and hydrogen ions take up the charge and plate out as hydrogen atoms and thus maintain the system electrically neutral. This primary reaction is followed by either the destruction of the film of hydrogen by reacting with dissolved oxygen:

$$\text{(b)}\quad \underset{\text{hydrogen atoms}}{2H^\circ} + \underset{\text{dissolved oxygen}}{\tfrac{1}{2}O_2} \rightarrow \underset{\text{water}}{H_2O}$$

or the hydrogen can be removed as bubbles of gas:

$$\text{(c)}\quad \underset{\text{hydrogen atoms}}{2H^\circ} \rightarrow \underset{\text{hydrogen gas}}{H_2}$$

Reactions (b) or (c) must take place in order to permit reaction (a) to proceed. Otherwise, the presence of the hydrogen film obstructs further progress of the primary reaction either by insulating the iron from the solution or by the increasing tendency of the hydrogen in the film as it is built up, to re-enter the solution and thus oppose the corrosion tendency.

In natural waters containing dissolved oxygen, reaction (b) is the controlling factor and corrosion is almost directly proportional to the oxygen content of the water.

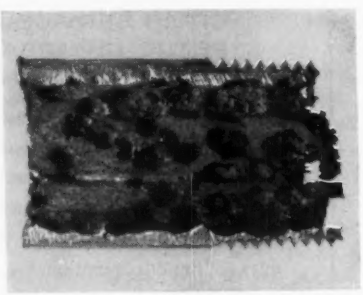


Figure 1 — Section of line showing pitting by dissolved oxygen.

The hydrogen ion in reaction (a) is available from ionization of water as follows:

$$\text{(d)}\quad \underset{\text{water}}{2H_2O} \rightleftarrows \underset{\text{hydrogen ions}}{2H^+} + \underset{\text{hydroxyl ions}}{2OH^-}$$

When hydrogen is plated out, the hydroxyl ions remaining cause an increase in the alkalinity adjacent to the point of corrosion. The ferrous ions entering solution will tend to precipitate as ferrous hydroxide. In the presence of dissolved oxygen, the ferrous ions will be oxidized to ferric hydroxide. Depending on the supply of oxygen, the resulting corrosion products will usually consist of black or green ferrous hydroxide next to the metal and reddish-brown ferric hydroxide which forms the outer layer, with graded mixtures of the two in between. The initial rate of corrosion is usually much greater than the rate after a longer period of time due to barriers set-up by the reaction products.

pH

At a pH below 4.3 (the region of free mineral acidity) the chief controlling factor in promoting corrosion is pH and the hydrogen film is removed by hydrogen evolution as shown by reaction (c). In the free mineral acid range the ferrous ions entering solution will remain soluble and therefore no insoluble reaction product will result. In the absence of a barrier the corrosion rate in acid solutions is therefore rapid. When the solution contains dissolved oxygen in addition to a pH value in the free mineral acid range, the rate of corrosion is further accelerated.

At a pH above approximately 9.5, as the alkalinity increases the pH or hydrogen ion activity decreases and the primary reaction as illustrated by equation (a) is slowed down. The rust coating formed in alkaline solutions is a more protective barrier than the one formed in neutral solutions. Therefore, the rate of corrosion is appreciably decreased and in fact in an alkaline solution, a negligible amount of corrosion will take place at normal temperatures and in the absence of dissolved oxygen. However, in the presence of dissolved oxygen, reaction (b) will still be controlling and while the rate of corrosion will be appreciably decreased a serious amount can still result.

At a pH between these limits (4.3—9.5) the presence of dissolved oxygen plays a more important role than the pH.

Dissolved Solids

In general, increase in dissolved solids content of a water increases the corrosivity. The electrolytic theory views the corrosion mechanism as an electrolytic cell. The iron metal provides both the anode and the cathode of the cell and the water is the electrolyte. At the anode,

For more data on advertised products, use Readers' Service Cards, last page.

the metal dissolves in the water, and in so doing it gives up two electrons which flow through the metal to the cathode where the electrons combine with the hydrogen ion to plate out hydrogen atoms as a film on the cathode. Various explanations have been advanced for the corrosive effect of higher dissolved solids. Higher dissolved solids increase the conductivity of the water thus favoring corrosion. One logical theory involves the effect of ions in destroying or altering the coating of corrosion products on the metal. A loose non-adherent coating under ordinary conditions may accelerate the rate of corrosion locally and produce a pitting condition, whereas a uniform, adherent coating may form an effective barrier and reduce the corrosion rate considerably. The chloride ion in particular exerts an adverse effect and within certain limits of concentration permits accelerated attack.

tact of dissimilar metals is known as galvanic action. The tendency of a metal to dissolve and enter solution as an ion is measured by the electrode potential between the metal and its ions. The listing of the electrode potential of the various metals constitutes the familiar

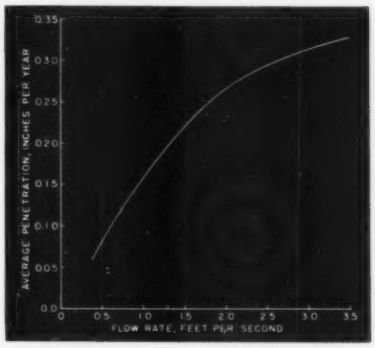


Figure 2—Influence of flow rate on corrosion.

ferrous bicarbonate, tends to elevate the pH and as the pH increases above 5.9, the reaction rate becomes reduced. The hydrogen formed in the reaction will also have a retarding effect particularly when the pH exceeds 5.9. The ferrous bicarbonate formed in the reaction is soluble and can be carried along with the condensate. When dissolved oxygen is also present, it will accelerate the rate of corrosion by removing the hydrogen to form water.

Other Factors

Corrosion of ferrous metals in the presence of moisture is a complex subject. Many other variables will affect the corrosion rate, such as homogeneity of the metal, condition of the metal surface, ratio of surface areas exposed by two dissimilar metals, static and cyclic stresses, oxygen concentration cells, etc.

INDUSTRIAL WATER SYSTEMS

Temperature

The chemical reactions of corrosion increase in rate with increase in temperature. Increased temperature decreases water viscosity and thus increases the diffusion rate of oxygen. Electrical conductivity is increased at higher temperatures, thus producing an effect similar to increase in dissolved solids. Pitting may be enhanced where adjacent metal areas vary in temperature, with the hotter sections anodic (more corrosive) to the colder areas.

Flow Rate

Increase in the rate of flow tends to increase the corrosion rate. Figure 2 illustrates data secured through the exposure of ¼" tubular low carbon steel specimens to Philadelphia (Delaware supply) tap water at a temperature of 120 F. The corrosion rate increases rapidly with increase in flow rate although at higher flow rates the influence is less pronounced. The influence of flow rate on corrosion is primarily due to the increase in supply of dissolved oxygen which destroys the hydrogen film in keeping with reaction (b).

Dissimilar Metals

The corrosion that occurs from the contact of dissimilar metals is known as galvanic action. The tendency of a metal to dissolve and enter solution as an ion is measured by the electrode potential between the metal and its ions. The listing of the electrode potential of the various metals constitutes the familiar Electromotive Series. The electrode potential of hydrogen is defined as zero. The metals that are higher in the series are considered able to displace those metals lower in the series.

The Electromotive Series cannot be taken as a precise indication of galvanic action. The potentials of various metals can be altered by ion concentration, temperature and the corrosive environment.

Carbon Dioxide

In a neutral water, taken from surface supplies where dissolved oxygen is present, the presence of carbon dioxide has little effect on the corrosion rate. However, many well waters, which are usually devoid of oxygen, will be found to contain appreciable amounts of carbon dioxide. In steam and condensate systems, it is possible to encounter serious corrosion from carbon dioxide even in the absence of dissolved oxygen.

When carbon dioxide dissolves in water it forms carbonic acid which is a weak acid and produces corrosion in keeping with the following reaction:

(a) Fe (iron) $+ 2H_2CO_3$ (carbonic acid) $\rightarrow Fe(HCO_3)_2$ (ferrous bicarbonate) $+ H_2$ (hydrogen)

The above reaction proceeds rapidly at a pH below 5.9. The reaction product, Water characteristics also are influenced by factors such as hydrogen sulfide, chlorine, and biological factors—all of which can accelerate markedly the corrosion rate.

Despite the complexity of the problem, great strides have been made in methods for control of corrosion. Continuing research by BETZ LABORATORIES has led to a better understanding of the effect of different variables, as well as provided increasingly effective control methods. A Betz Field Engineer will be happy to discuss your corrosion problem as it relates to any boiler, cooling or process water system.

No obligation, of course.

BETZ LABORATORIES, INC.
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■ CONSULTANTS ON INDUSTRIAL WATER PROBLEMS

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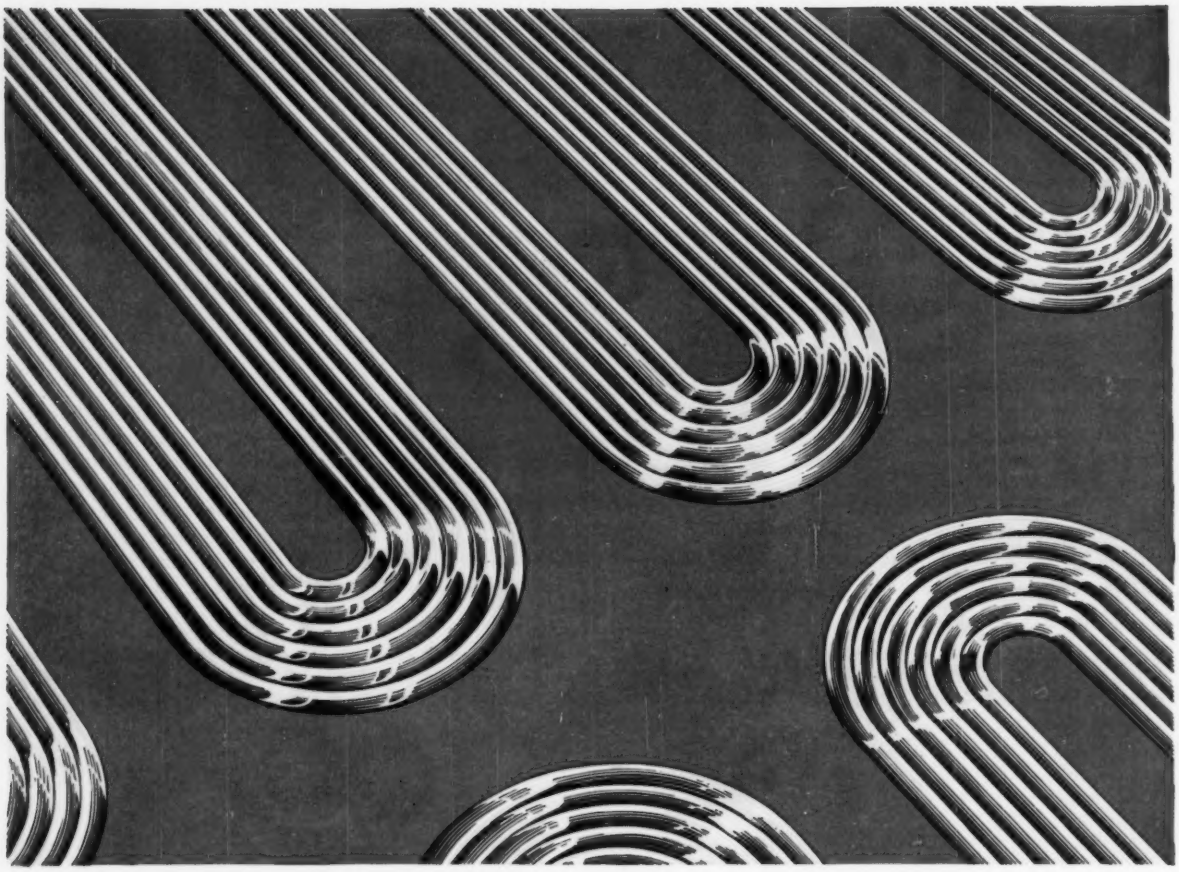

NOW! U-BEND HEAT EXCHANGER TUBES BY CHASE

save time, trouble, money . . . all these ways!

SAVE on installation costs by eliminating one tube sheet . . . halving welding or rolling-in operations.

SAVE because handling is minimized.

SAVE time, labor and equipment used to fabricate U-bend tube on the job site.

SAVE because U-bend eliminates need for floating heads by handling differential expansions.

SAVE by eliminating scrap. Tubes fabricated to specifications do away with waste-end scrap.

SAVE because pallet loading insures storage economy.

Now you can order *pre-fabricated* tubes from Chase. That means you can realize the many on-the-job advantages of U-Bend tube, and at the same time be sure of *quality*.

Chase tube is manufactured under constant production control. Relief annealing immediately after bending avoids possible stress-failure later; precision hydrostatic testing of bends detects any possible hidden defects.

Chase U-Bend tube is available in uniform gauge, as well as with thickened center. Sizes range from ⅝" o.d. to 1" o.d., bent on radii from ⅞" to 25" depending on your requirements.

When ordering, be sure to include the following information: O.D. and I.D. in inches; wall thickness; length; quantity; alloy or material; temper; bend radius; length of thickened portion on dual-gauge tubes. Talk your specific needs over today with your nearest Chase office, or write Chase at Waterbury 20, Connecticut.

Chase®

BRASS & COPPER CO., WATERBURY 20, CONN.

Subsidiary of ***Kennecott Copper Corporation***

MADE IN U.S.A. TO THE STANDARDS OF AMERICAN NO. 100 BRASS & COPPER

THE NATION'S HEADQUARTERS FOR ALUMINUM • BRASS • BRONZE • COPPER • STAINLESS STEEL

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Now...put your whole team ON THE FIRE!

More than a quarter of a million gallons of expanded FOAM using just one 1000-gal. tank of ROCKWOOD Double-Strength FOAM liquid! That's the amazing fire-fighting power of this compact, ROCKWOOD-equipped truck at a large eastern oil refinery.

ROCKWOOD Automatic Controls permit delivery of FOAM or water from any or all of six 2½" FogFOAM Nozzles and Direct Manual Turret at any desired rates. System includes 500-gal. "starter" water tank.

Let Rockwood handle variable flow rates automatically

Now you can set and forget FOAM liquid injection rates . . . release that "extra man" for *active* duty!

ROCKWOOD Balanced Pressure Proportioning System will automatically maintain FOAM liquid percentage precisely where you set it at any flow rate. No adjustment with valves and meters . . . no constant gage watching. Operate line outlets and turret individually or in any combination to deliver desired FOAM solution or water simultaneously; you're sure of maximum flexibility and complete reliability under all fire conditions.

ROCKWOOD Proportioning System gets you into action faster, too . . . keeps you going longer: water tank handles supply while you're hooking into local source. Tank of ROCKWOOD Double-Strength FOAM liquid doubles FOAM-making ability . . . halves storage space!

Get complete details on ROCKWOOD Proportioning System and ROCKWOOD Double-Strength FOAM liquid. It's the high-efficiency, extra-economy combination for all hydrocarbon fire situations. Tested and listed by Underwriters' Laboratories, Inc.

ROCKWOOD SPRINKLER COMPANY
Engineers Water . . . to Cut Fire Losses

ROCKWOOD Double-Strength (3%) FOAM Liquid

- Costs less for equal coverage
- Doubles FOAM-making ability per unit volume
- Reduces handling and transportation costs by 50%
- Cuts storage space in half
- Protects in all weather

ROCKWOOD SPRINKLER COMPANY
Portable Fire Protection Division
500 Harlow Street, Worcester 5, Massachusetts

Please send me details on Balanced Pressure Proportioning System and Double-Strength FOAM liquid.

Name.....
Title.....
Company.....
Street.....
City.....*Zone*....*State*.....

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ANNOUNCING NEW **POWELL**

Handwheel Nut—securely holds malleable iron, non-heating handwheel to the stem.

Protruding Packing Gland—a Powell feature—compresses the packing, offers additional guidance to the stem, and prevents packing nut from becoming loose and rotating with stem.

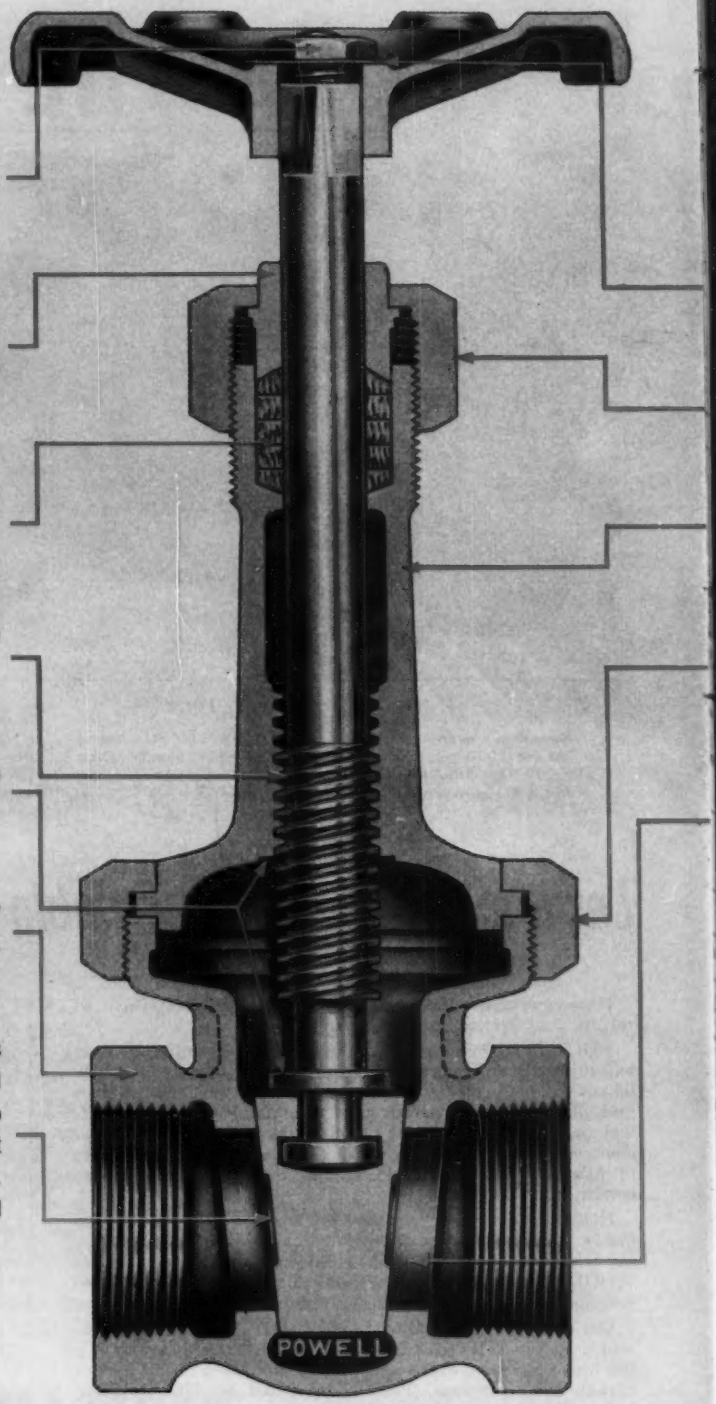
Deep Stuffing Box—holds more than ample amount of high-grade steam packing.

Stem—is high tensile bronze, extra heavy, of large diameter, with long Acme threaded section.

Repack-Under-Pressure Seat and Collar—permit valve to be repacked under pressure when fully open.

Body—a high tensile bronze casting, scientifically designed to provide full flow area through the valve.

Wedges—Interchangeable Solid or Double Wedges are available in rising stem valves. They are held to stem by a "T" slot, and are accurately guided to valve seats by means of integral cast lugs that travel in female guideways in the valve body. Entirely clearing the waterway, full unobstructed flow through is assured.



Sectional—Union Bonnet Rising Stem Gate Valve Fig. 2700—125 pounds, Fig. 2714—150 pounds.

POWELL...world's largest family of valves

BRONZE UNION BONNET GATE VALVES

for 125 and 150 pounds WSP

These new BRONZE Union Bonnet Gate Valves have many superior features—some of which are outlined here. For complete details, write for new illustrated circular. Or check with your nearest Powell Valve distributor.

Identification Plate—gives Figure Number and kind of valve.

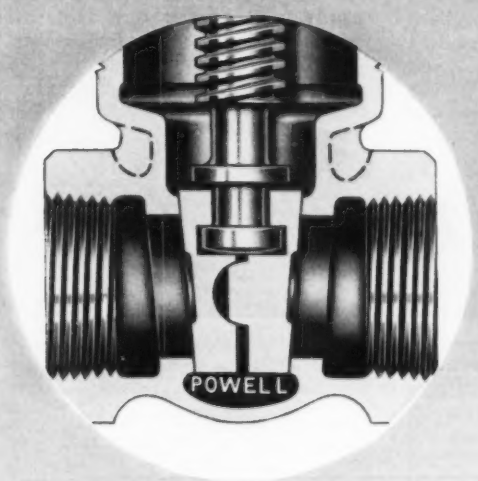
Heavy Hexagonal Packing Nut—for holding gland and adjusting packing.

Long Bonnet—cast of high tensile bronze for long service.

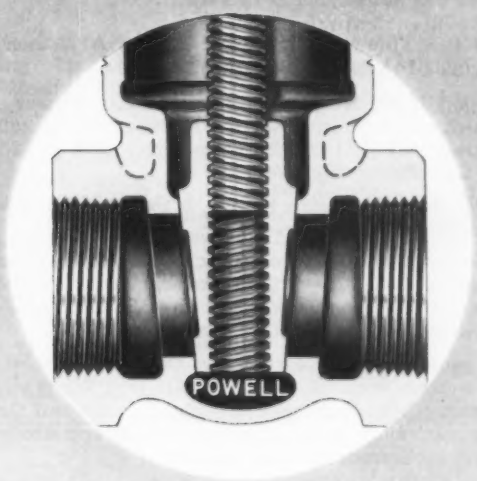
Octagonal Ring Nut—is deep threaded and tightly holds body-bonnet connection. Affords additional wrenching positions.

Ample Space—between seats and end of pipe thread prevents injury to seats when screwing pipe into the body.

Fig. 2707—125-pound Union Bonnet Non-Rising Stem Gate Valve. Also available for 150 pounds—Fig. 2712.

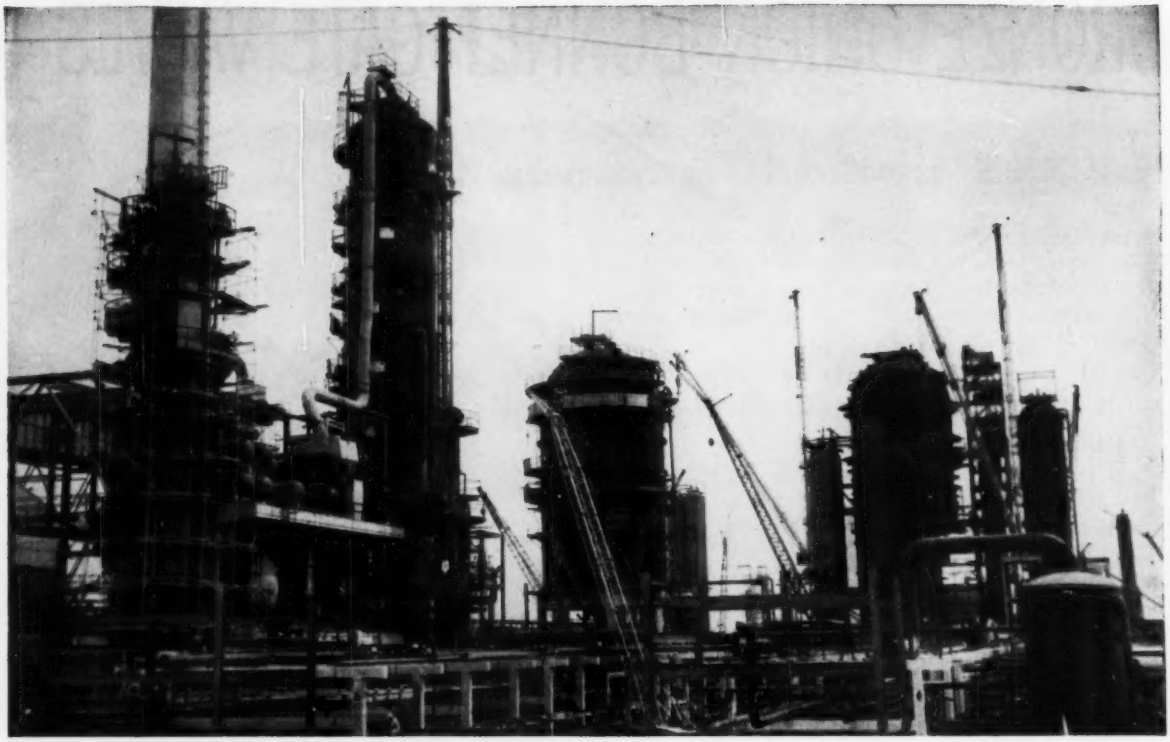


Detail of Sectional View Inside Screw Rising Stem Gate Valve showing Double Wedge Disc and Integral Seats.



Detail of Sectional View Non-Rising Stem Gate Valve showing Solid Wedge Disc that rises on stem. Integral Seats.

THE WM. POWELL COMPANY • *Dependable Valves Since 1846* • **Cincinnati 22, Ohio**



A dozen vessels built by Newport News were furnished under contract with C. F. Braun, Inc., of Alhambra, Calif., design engineers for the ultra-modern Delaware Flying A Refinery of the Tidewater Oil Company located 15 miles south of Wilmington.

Newport News builds 12 major components for new Flying A 130,000-bpd refinery

This is the Tidewater Delaware Flying A Refinery while under construction near Wilmington.

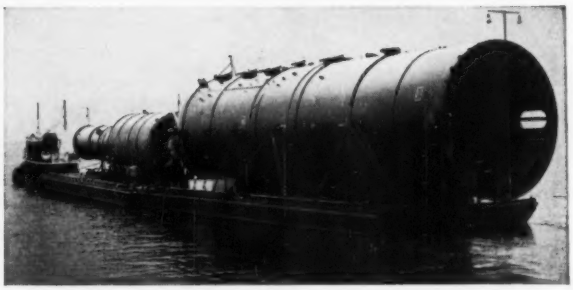
Newport News fabricated 12 of its major vessels — 2 of which are the largest such units ever built: a 250′ Orthoflow fluid "cat cracker" converter and a 225′ reactor scrubber of the fluid coker.

More notable than size, though, is the quality of the Newport News fabrication.

Coke-out screens in the reactor scrubber, for example, are made of 704 12% chromium segments. Welded together with accuracy, they provide 45% clear opening . . . with opening tolerances less than 1%.

You get expert fabrication, the skill of specialists when Newport News builds your equipment. When you want reactors, pressure vessels, vacuum tanks and the like, sub assemblies or weldments in almost any size or shape, get a bid from Newport News.

Send for newly published, easy-to-read, illustrated booklet, "Facilities and Products". It describes the many ways in which Newport News can help you with present or future projects. Write for your copy today.



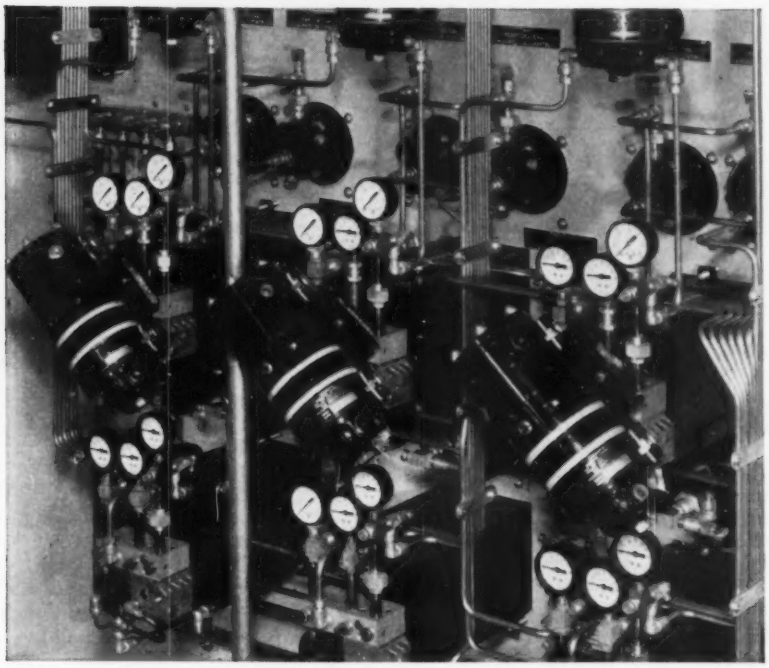
Full advantage was taken of the Newport News deep water loading facilities for transportation of all of the equipment by barge. Shop erection prior to shipment assured fast, trouble-free field assembly.

Engineers: Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

Newport News Shipbuilding and Dry Dock Company, Newport News, Virginia

IMPERIAL Engineering and Data File

ENGINEERED TUBE FITTINGS — VALVES — TUBING TOOLS



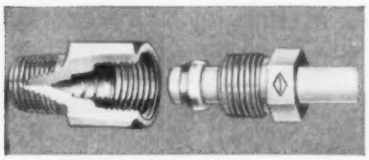
Leakproof connections quickly made with Hi-Duty tube fittings on refinery control boards

Tube fittings that assemble to tubing fast and provide assurance against leaks are one of the top requirements for control boards.

That's why Panellit selected Imperial Hi-Duty fittings on this panel board used for automatically controling a variety of oil refinery processes.

Hi-Duty Fittings have a one-piece nut and sleeve. A joint is made simply by pushing tube into fitting and tightening nut. Sleeve shears off and becomes permanently attached to tube. One man can easily assemble up to four Hi-Duty fittings in the time it takes to assemble one flare fitting. Hi-Duty assembles one-third faster than compression fittings and can be disconnected and reconnected repeatedly without leakage. And they withstand five times as much vibration as compression or flare fittings.

Write for Bulletin No. 3002

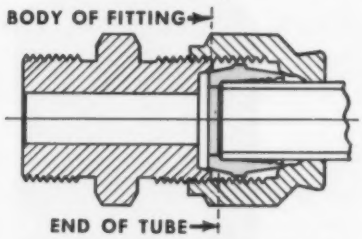


Disassembled Hi-Duty Fitting shows how sleeve has become permanently attached to tube.

HOW HI-DUTY SAVES 36% TO 72% ON INSTALLATION TIME!

TYPE OF FITTING	AVERAGE TIME FOR EACH JOINT	JOINTS PER HOUR
HI-DUTY	11.7 sec.	307
Regular compression	18.5 sec.	194
Flare	48.2 sec.	74

These studies were made under actual shop conditions.



Limited space? Solve it with Hi-Seal Fittings

Exclusive design of the Hi-Seal body, sleeve and nut creates the perfect butt joint . . . without threading or flaring. This butt joint is ideal for close quarters . . . the tube swings into place without springing or dismantling other components.

Because no flaring is necessary with the Hi-Seal butt joint, bends can be made exceptionally close to the ends of the tube . . . another major benefit where space is limited.

Key to high performance, even under high pressure conditions, is the sleeve with its base shoulder and 3 radial serrations. Camming action of nut causes sleeve to form a collet-type, triple seal grip on tube. Fittings meet J.I.C., A.S.A. and A.S.M.E. standards.

These fittings are available in stainless steel, steel and brass. Hi-Seal stainless steel fittings resist corrosive atmospheres and conditions of corrosive liquids and gases at high pressures.

Write for bulletin 3061

Free handbook tells how to work with tubing

This practical book tells you how to cut, flare, bend, swage, ream and solder tubing . . . fully describes modern tube-working practice.

Handbook No. 369

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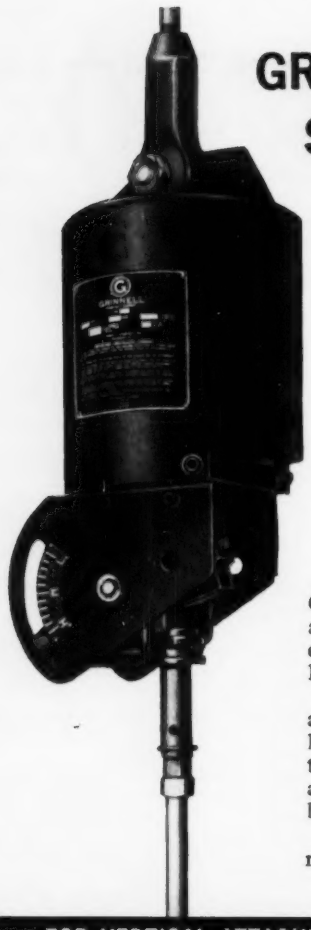
GRINNELL CONSTANT SUPPORTS...



2 BASIC DESIGNS...

11 DIFFERENT METHODS OF ATTACHMENT

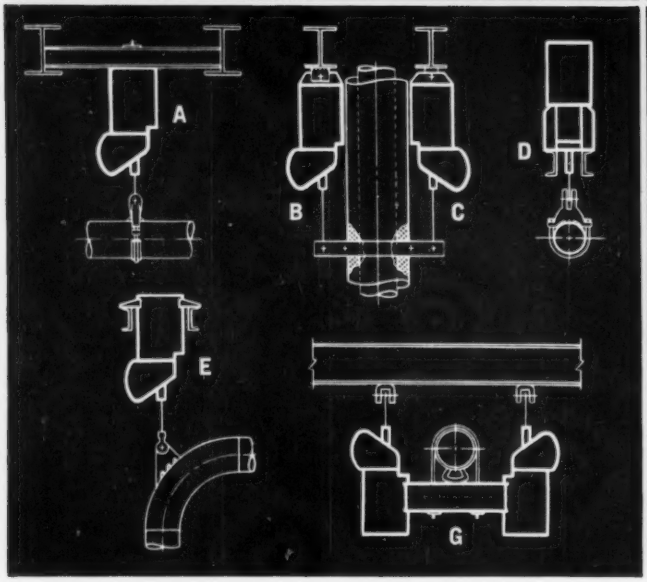
Grinnell Constant Supports are available in a range of sizes to provide capacities for loads from 27 lbs. to 57,500 lbs., with travels up to 16 inches.

Both vertical and horizontal hangers are designed to operate in extremely limited space. In the selection of types, there is a choice of 11 methods of attachment to structures—either above, between, or below supporting steel.

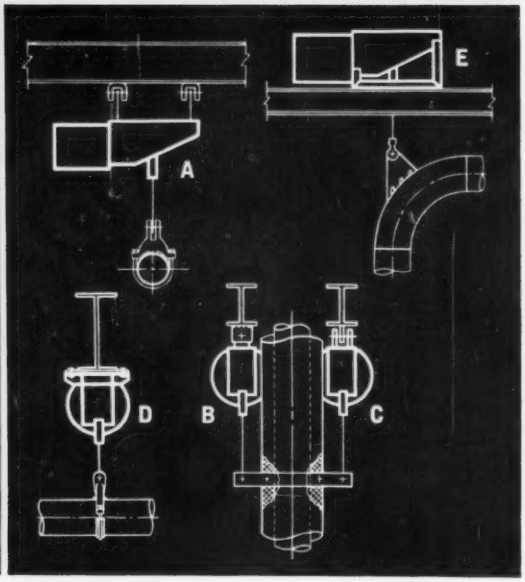
Grinnell Constant Supports provide mathematically perfect load support throughout all positions of travel . . . also a full 70 percentage points of adjustability is built into them. No less than 10% of this adjustability is allowed either side of calibration for plus or minus change in load. Field readjustments are easily made by turning a single load adjustment bolt.

Call on Grinnell's Pipe Suspension Department for help with your pipe suspension problems. Grinnell Company, Providence 1, Rhode Island.

FOR VERTICAL ATTACHMENT



FOR HORIZONTAL ATTACHMENT



GRINNELL

AMERICA'S No. 1 SUPPLIER OF PIPE HANGERS AND SUPPORTS

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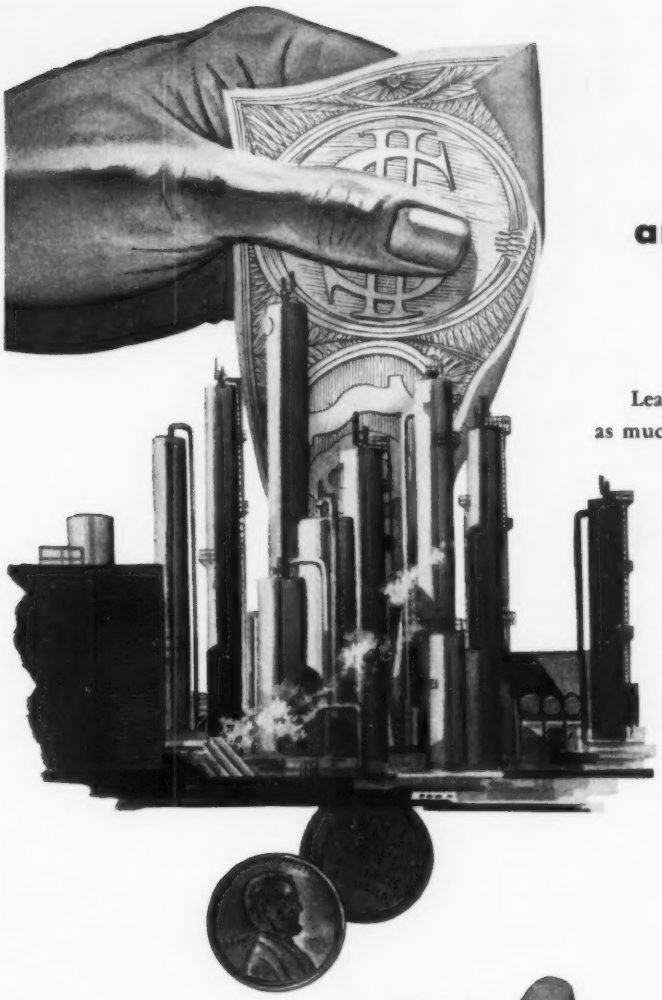

Are you feeding your refinery DOLLARS . . . and getting PENNIES back in return?

Leading oil economists declare that any processing unit as much as ten years old is probably costing you money.

EXAMPLE:

Most older units utilize furnaces and heaters with only 50% thermal efficiency. Today, good design and economics dictate at least 75% efficiency.

EXAMPLE:

A ten-year-old cat cracker may require up to one-half more operating personnel than a modern unit.

EXAMPLE:

Most crude units built ten years ago needed to be shut down every six months. Modern design often permits operations of twice that length.

If outdated units are eating up your profits, talk with a Treco man about replacing or revamping them. And remember . . . equipment costs are lower today than you can expect for years to come. There has never been a better time to modernize.

Licensing agreements permit Treco to furnish just about any modern processes available. Although we frequently handle process design on a custom basis we own no patented processes and manufacture no refinery equipment. This leaves us free to recommend and use whatever best fits your requirements.

....talk with the TRECO man.....

TRECO

A DIVISION of VITRO CORPORATION of AMERICA

The REFINERY ENGINEERING Company

TULSA • TORONTO BRANCH OFFICES IN OTHER STRATEGIC LOCATIONS

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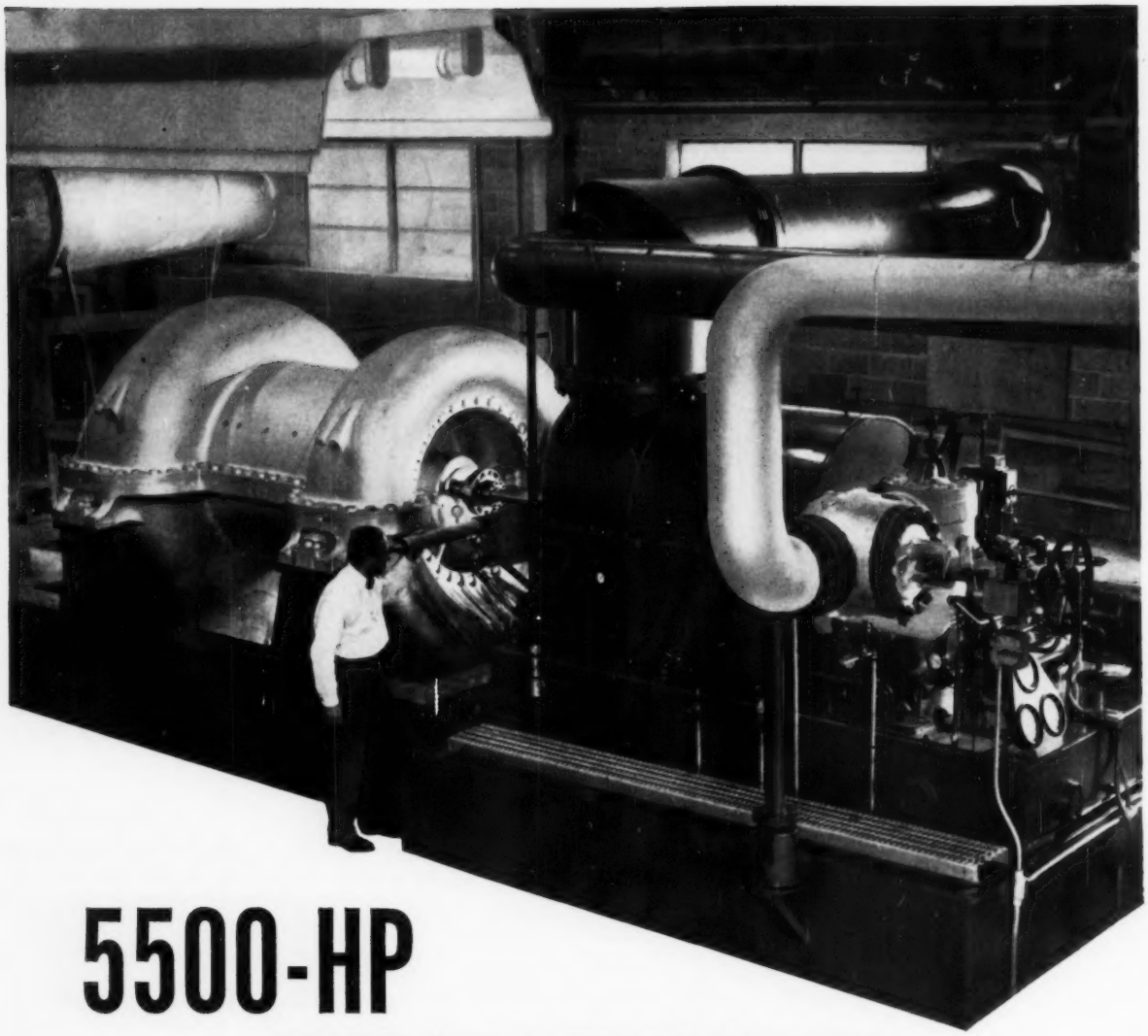

5500-HP TERRY TURBINE

plays an important role in compressor testing at Joy

Joy Manufacturing Company puts Terry high-speed turbine reliability to good use in its development facility at Buffalo, New York. This 5500-hp multistage turbine is used for testing centrifugal and axial-flow compressors. It provides speeds up to 9,000 rpm.

The long, trouble-free life of Terry high-speed turbines stems from two sources: (1) more than 50 years of successful experience in making turbine drives *exclusively*, (2) a willingness to build *something extra* into each machine to assure its reliability.

There's a reliable Terry turbine for you in sizes up to 6000 hp. In special cases higher outputs can be supplied.

For more information about Terry multistage turbines, ask for a copy of bulletin S-146.

TERRY

THE TERRY STEAM TURBINE COMPANY
TERRY SQUARE, HARTFORD 1, CONN.

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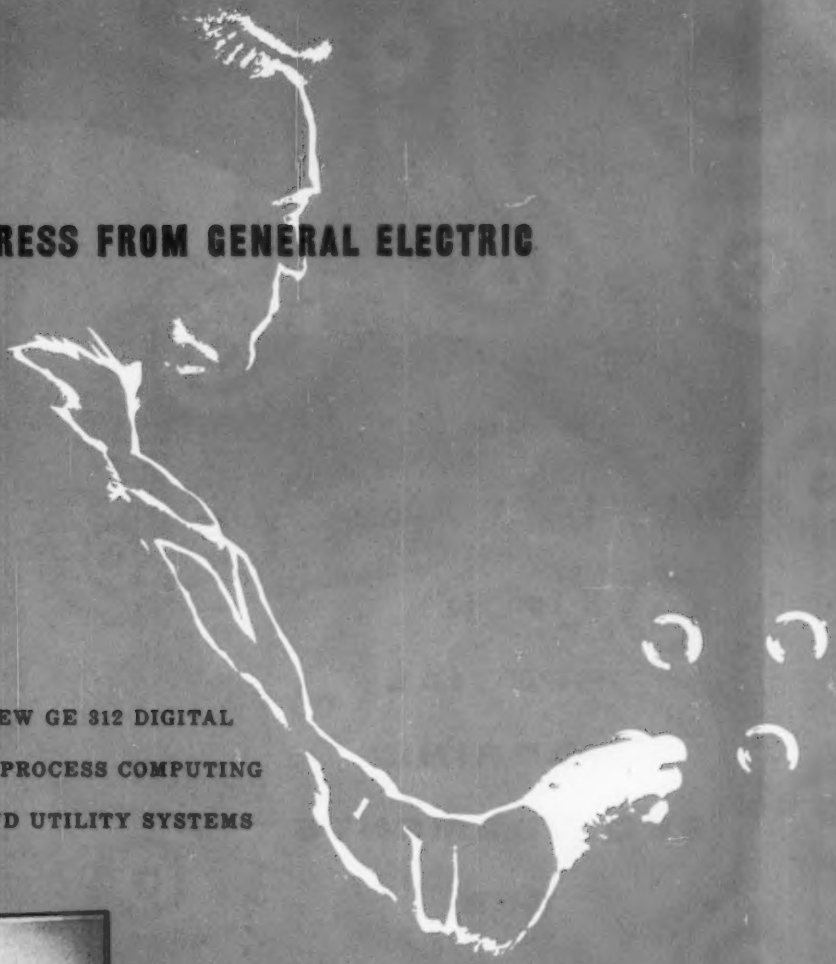
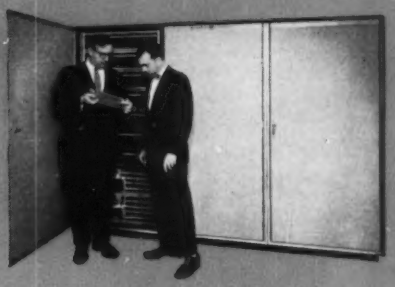
COMPUTER PROGRESS FROM GENERAL ELECTRIC



ANNOUNCING THE FLEXIBLE NEW GE 312 DIGITAL CONTROL COMPUTER FOR ON-LINE PROCESS COMPUTING APPLICATION IN INDUSTRIAL AND UTILITY SYSTEMS



GE 312 DIGITAL CONTROL COMPUTER

Newest member of a distinguished family of General Electric computers, the GE 312 *transistorized* DIGITAL CONTROL COMPUTER has been especially designed for process control, data logging, and data processing requirements imposed by industrial and utility operation.

• "Big Machine" features—moderate in cost • Expansible memory capacity • Easily programmed • Advanced programming aids available • Rugged construction for industrial application • Off-line operation as a general purpose computer

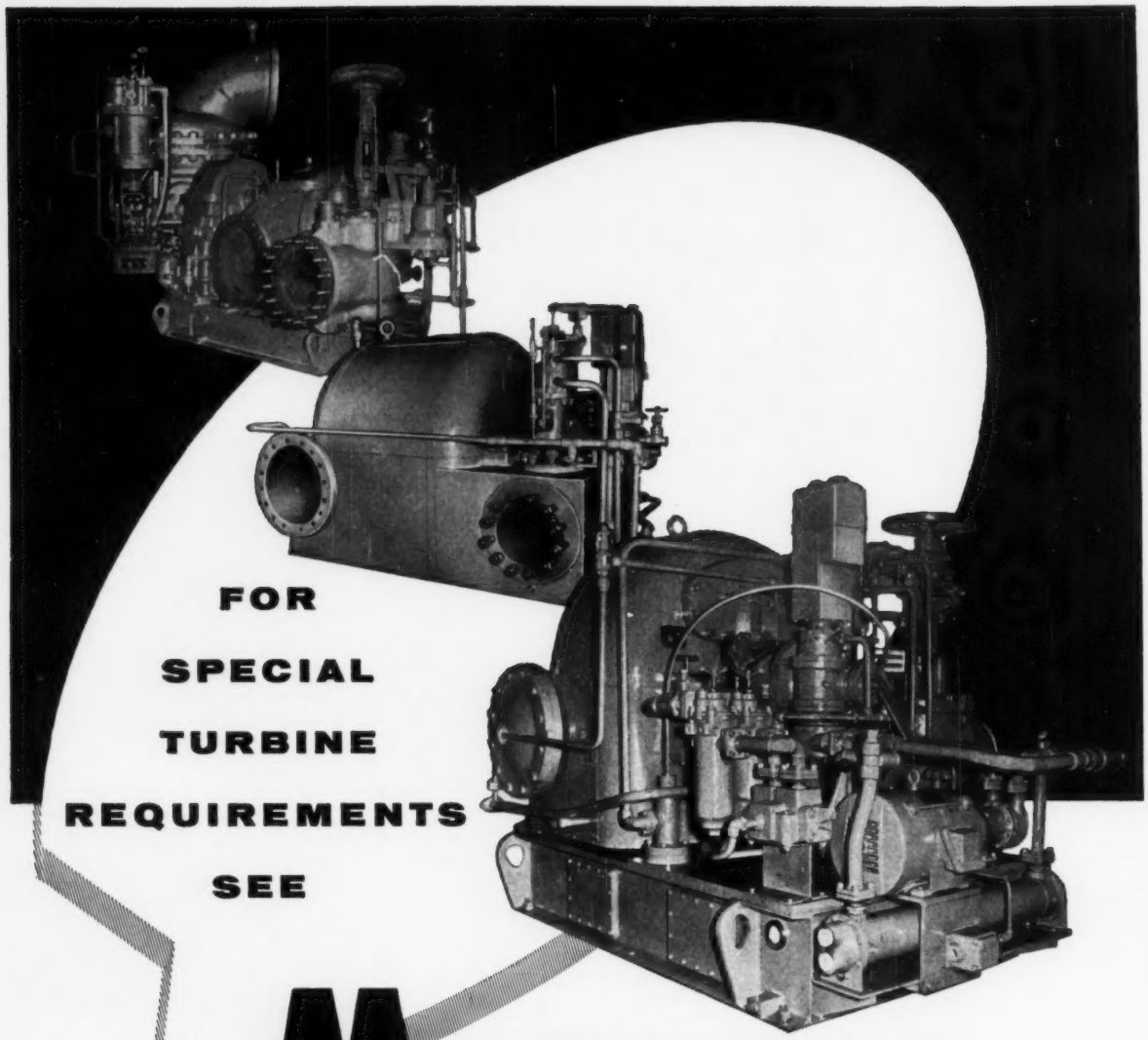
Request brochure CPB-36. For more information on computers, computing control and automation, contact your nearest General Electric Apparatus Sales Division Office, or write to: Computer Department, Room 3300A General Electric Company • Deer Valley Park • Phoenix, Arizona.

Progress Is Our Most Important Product

GENERAL ELECTRIC

FOR FIGURES IN A HURRY—FIGURE ON A GE COMPUTER

CPA-16 (5-60)



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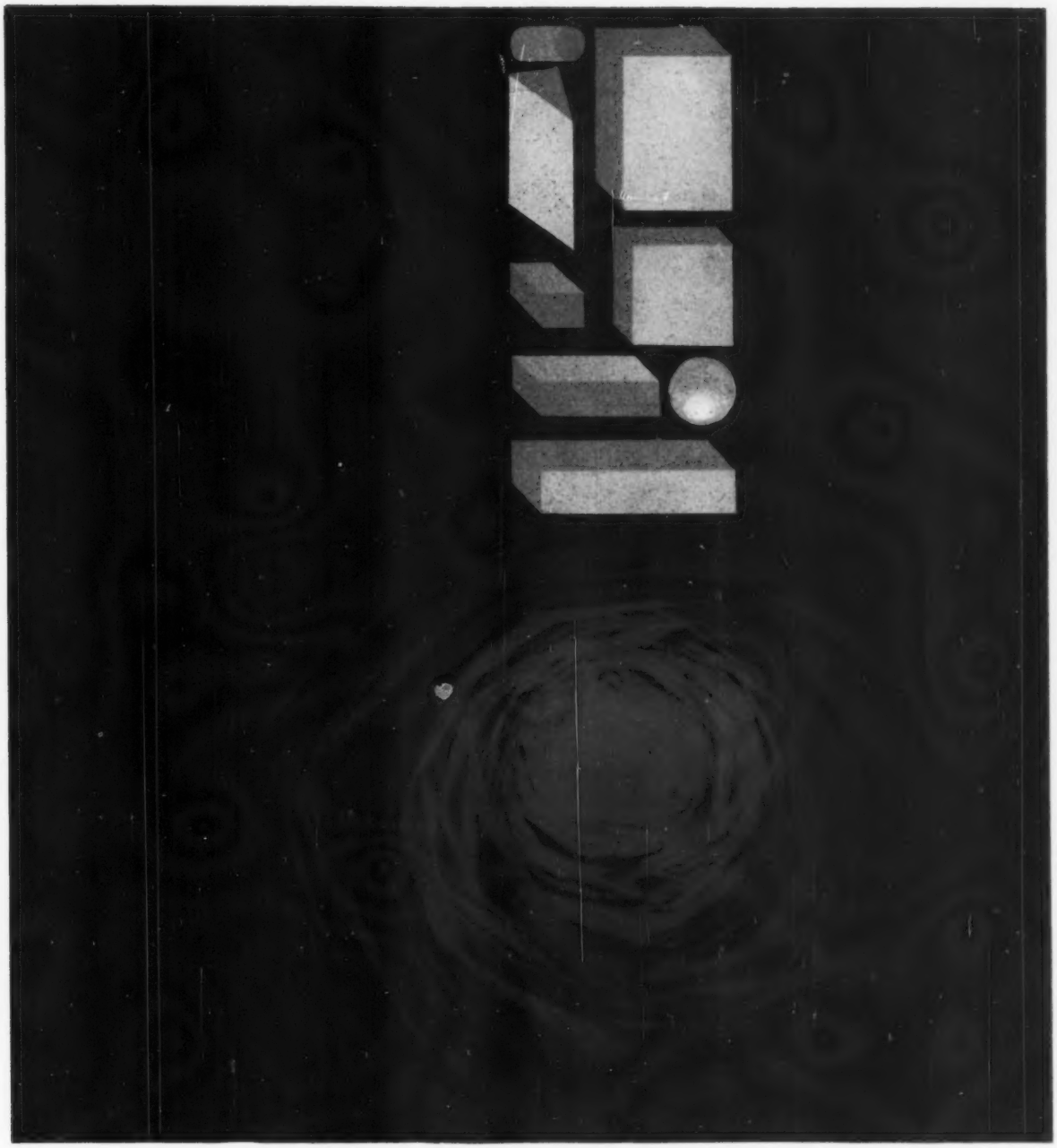
Our nearest representative will help you solve your turbine requirements. His name gladly sent on request.

MURRAY IRON WORKS COMPANY • BURLINGTON, IOWA

Builders of Steam Power Equipment for Nearly a Century



Don't let rising process heats ruin your refractories

...or your profits... *mix imagination with Alcoa Aluminas*

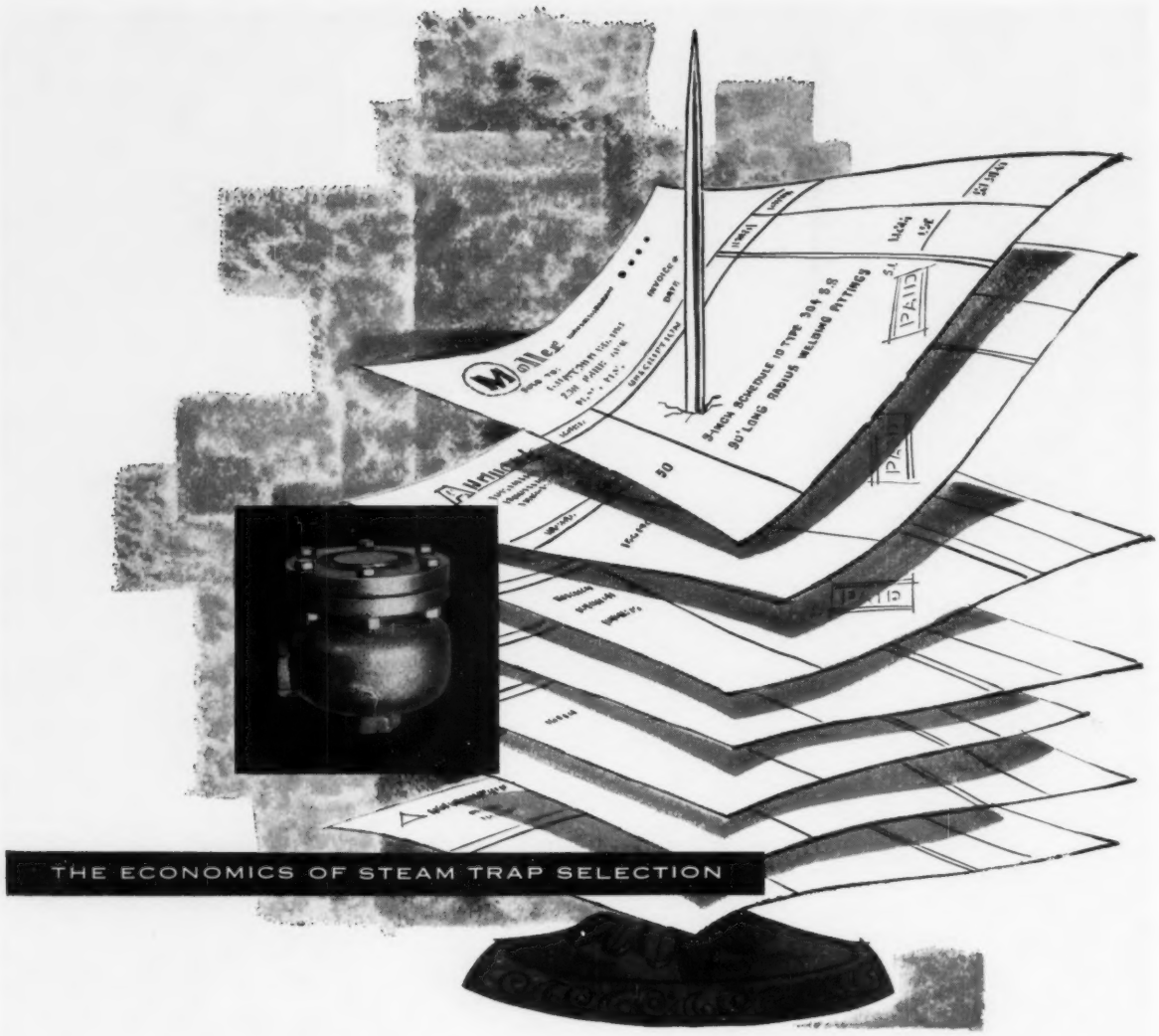
The steady increase in general process temperatures poses no problem at all for refractories fortified with ALCOA® Aluminas. Their refractoriness rises in direct proportion to the amount of alumina in their composition. These high-purity aluminum oxides also add greatly to strength and stability under load at elevated temperatures. And high-alumina refractories are chemically stable, immune to both oxidizing and reducing atmospheres. They offer just one more illustration of the many good reasons why makers and users of a variety of products have found it pays to *mix imagination and engineering with Alcoa Aluminas . . . to make an old product better or a new product possible.* Discover what ALCOA Aluminas can do for your own product or process. Outline your requirements in a letter to ALUMINUM COMPANY OF AMERICA, CHEMICALS DIVISION, 708-F Alcoa Building, Pittsburgh 19, Pennsylvania.

For finer products...let Alcoa add new dimension to your creative thinking!

ALCOA CHEMICALS

For exciting drama, watch "Alcoa Theatre," alternate Mondays, NBC-TV, and "Alcoa Presents," every Tuesday, ABC-TV

For more data on advertised products, use Readers' Service Cards, last page.



When is the first cost the last cost?

One way to find out is to examine the service records of steam trap installations. Start with a new installation, then learn how long the traps remained in service before they had to be replaced.

At replacement time, was the same brand specified? Or was it found to be inadequate, and a better trap substituted? If substitution was made, why didn't the buyer choose the better brand in the first place?

First cost is last cost only when useful service life, not initial price, is the primary consideration. ST-101

NICHOLSON

OF WILKES-BARRE

W. H. Nicholson and Co. • 14 Oregon Street • Wilkes-Barre, Pa.

Distributors in all principal cities

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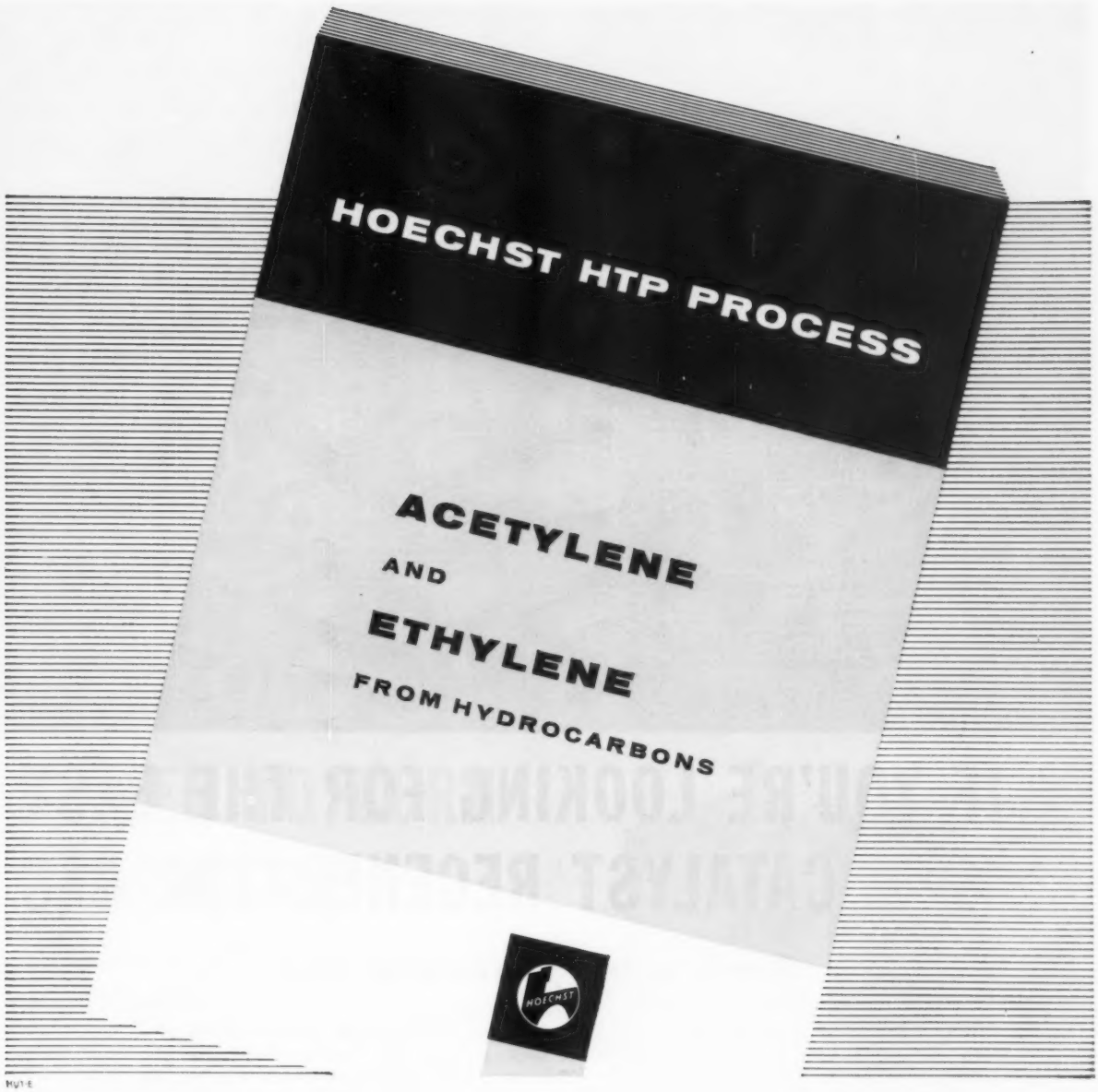

Further information may be obtained from:

HOECHST-UHDE INTERNATIONAL GMBH Frankfurt (M)-Hoechst, Germany

For United States and Canada from:

HOECHST-UHDE CORPORATION Empire State Building, New York 1

THE LUMMUS COMPANY 385 Madison Avenue, New York 17

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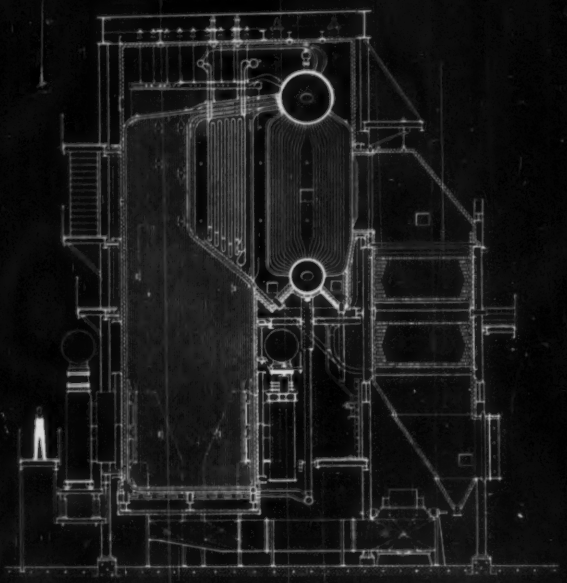
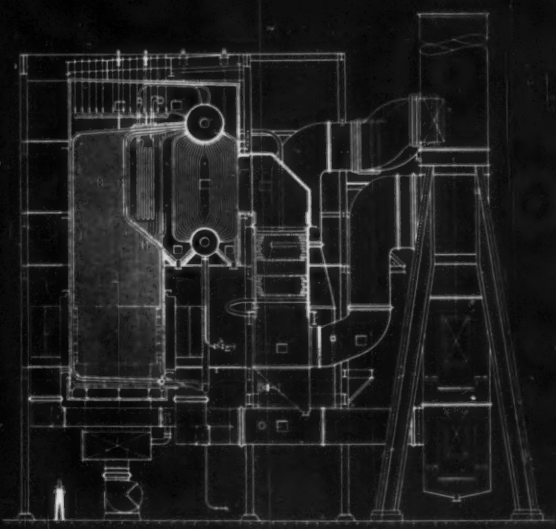
This unit delivers 175,000 lb of 750F steam per hour at 650 psig. In addition to CO gas, it burns pitch, refinery gas and Bunker C oil.



One of two CO boilers for a Texas refinery. Oxygen for combustion is supplied by the exhaust from the gas turbines which drive the regenerator compressors. Steam conditions are 177,000 lb per hr, 625 psig and 700F.



IF YOU'RE LOOKING FOR THE BEST CATALYST REGENERATOR GAS

Here are 8 reasons why

1. **YOU'LL WANT HIGH AVAILABILITY**
   And the records show that the first CO Boiler placed in service by C-E has been on the line for more than two years without a single unscheduled boiler outage.
2. **YOU'LL WANT OPTIMUM RETURN**
   And CO Boilers by C-E burn regenerator gas efficiently *from minimum to maximum loads.*
3. **YOU'LL WANT LOW POWER CONSUMPTION**
   And CO Boilers by C-E provide minimum air pressure loss and minimum fan horsepower requirements.
4. **YOU'LL WANT LOW MAINTENANCE**
   And double steel, skin cased CO Boilers by C-E contain a minimum of exposed refractory.
5. **YOU'LL WANT THE MOST EFFECTIVE USE OF MATERIALS**
   And C-E makes optimum use of boiler and superheater – gas passage areas and heating surfaces are uniformly distributed across the width of the unit.
6. **YOU'LL WANT ADVANCED DESIGN**
   And C-E Tangential Burners provide complete and positive mixing of air, auxiliary fuel and CO gas, preparing the combination for instantaneous ignition on injection in the furnace.
7. **YOU'LL WANT MAXIMUM CONTROL OF THE COMBUSTION PROCESS**
   And CO Boilers by C-E offer individual, shielded cut-off dampers for each CO gas burner and individual air control for every burner.
8. **YOU'LL WANT A PRODUCT THAT HAS PROVEN ITSELF**
   In terms of general experience, a total of more than 675 tangentially fired C-E boilers have been purchased to date for use with various fuels. As to specific experience with lean fuels, C-E – in addition to its CO Boiler installations in refineries – has installed more than 150 boilers burning blast furnace gas . . . a fuel similar to CO gas with a heating value of about 80 Btu per cubic foot.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;

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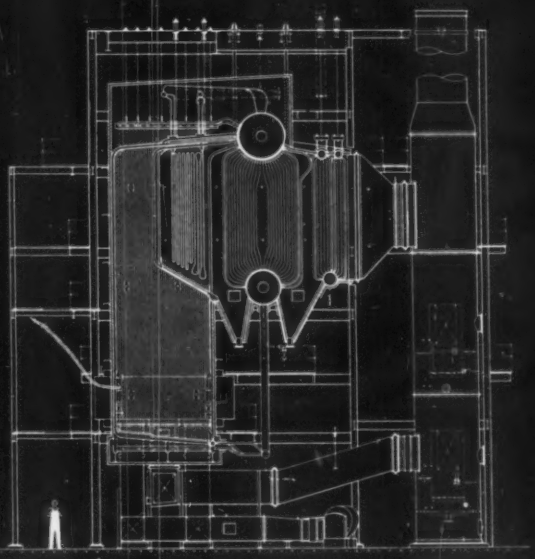
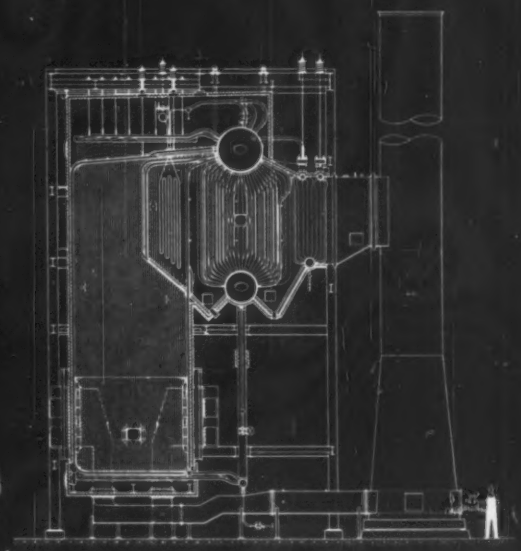
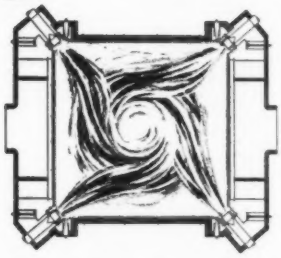
This unit is designed to produce 85,000 lb of 750F steam per hour at 625 psig. Note the C-E seal tank arrangement in the bottom-supported stack.



In its third year of service, this unit provides 100,000 lb of 550F steam per hour at a pressure of 250 psig. It has been off the line only when the cat cracker was removed from service for scheduled maintenance.

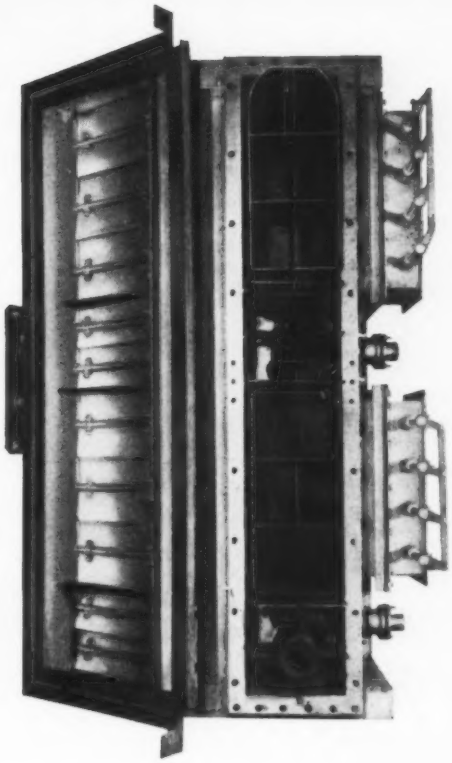


BOILER TO BURN *See* C-E



Plan view diagram showing principle of tangential firing in a completely water-cooled furnace.

The C-E Tangential Burner for CO gas. Zone controlled, dampered air inlets are shown at left, dampered CO gas inlets at right. The center panel is a furnace view of the burner The oil burners in the cen ter and bottom compartments are flanked by flat head burners for natural or refinery gas firing. CO gas is admitted through the other ports.



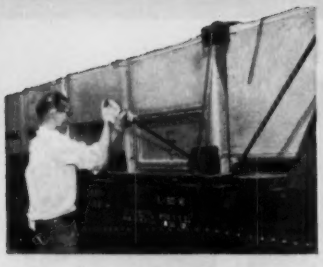
COMBUSTION ENGINEERING

C-148

Combustion Engineering Building
200 Madison Avenue, New York 16, N. Y.

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

newest Westvaco "first" saves money for Ba users!



Illustrations show 5,000 lb. capacity bins being loaded on flat car. Bins have feet which fit in slots to hold them securely in place. When car is fully loaded, cables are tightened and it's ready to roll.

Like many other Westvaco customers, you might be able to realize substantial savings on barium chemicals in these easy-handling, moisture-tight shipping and storage bins. Your nearest Westvaco office will gladly assist in estimating the possible economies in terms of your specific operation.

This modern, money-saving package is the most recent in a series of customer-minded product and service innovations in Westvaco Barium that result from our years of experience.

Through the years we have cooperated with lube oil and other barium users to pioneer new products best suited to their needs. As a result, we offer the widest range of barium products made, backed by fully integrated production and an unmatched record of dependability.

fmc
FOOD MACHINERY AND CHEMICAL CORPORATION ®

Putting Ideas to Work

FOOD MACHINERY AND CHEMICAL CORPORATION
Westvaco Mineral Products Division

General Sales Offices:
161 E. 42nd STREET, NEW YORK 17

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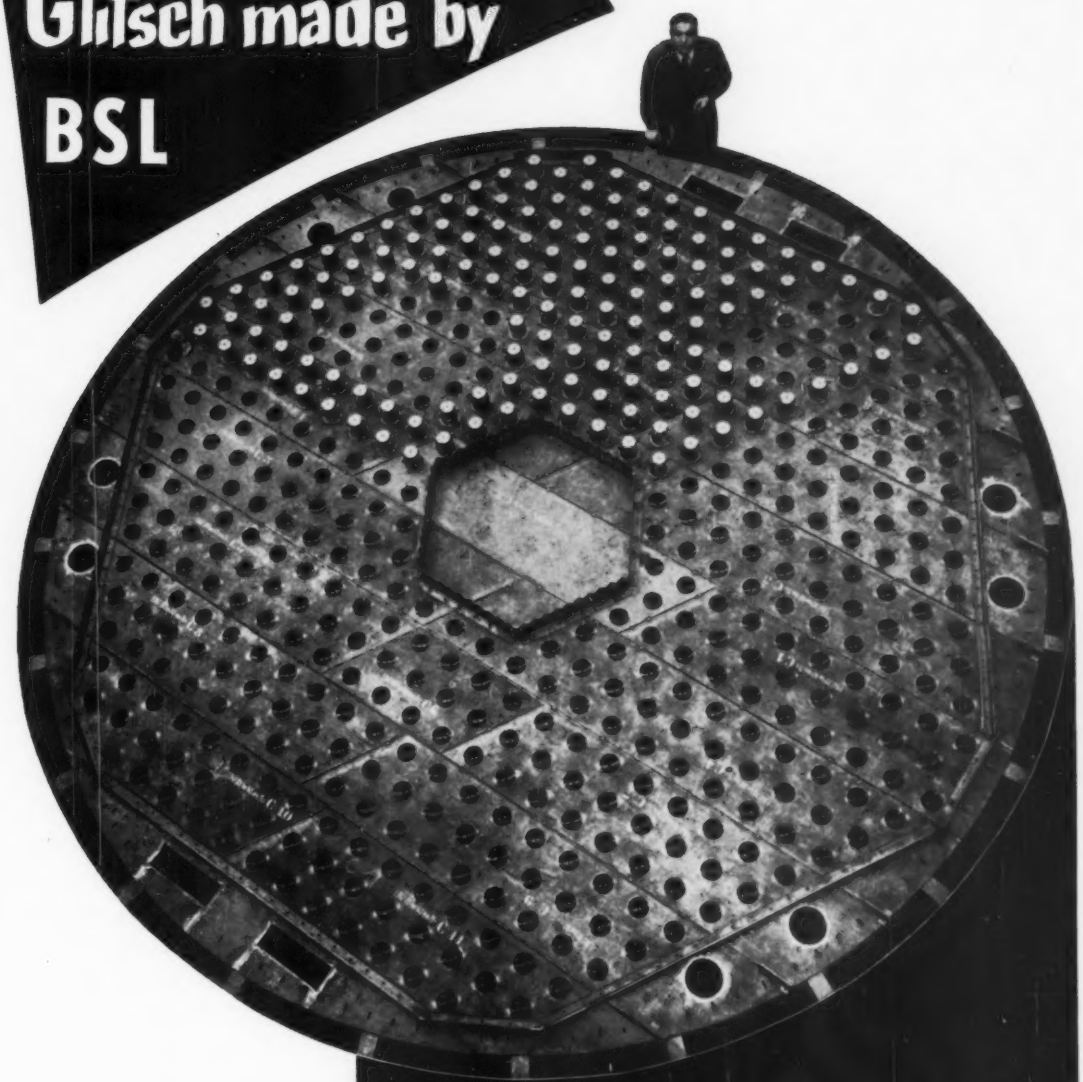
A wonderful American success in Europe :

Glitsch made by BSL

R.L. Dupuy



Bubble tray, fabricated from 12 % chrome alloy steel with hexagonal type weir designed for à 22'-0" diameter tower.

BSL

BIGNIER, SCHMID-LAURENT

Stainless Steel Specialists
25, quai Marcel Boyer - Ivry (Seine) FRANCE
Téléphone : ITAlie 53-89
Cableaddress : BSL Ivrysurseine

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what's the secret

why is Caposite so strong?

It's no secret why CAPOSITE insulation is so strong and stands up to such rough usage. These pipe sections and blocks are made wholly of Amosite asbestos and the long fibres of this particular kind of asbestos give CAPOSITE its strength and resilience as well as its high insulating value.
This exceptional strength leads to many other features besides long life; it means that larger sizes of pipe sections and blocks are possible, making application easier and faster. Less care is needed in handling the material. Unlike other moulded insulation, CAPOSITE, because of its strength, can be shipped to refineries anywhere in the world *in cardboard cartons*, showing big savings in freight and storage costs.

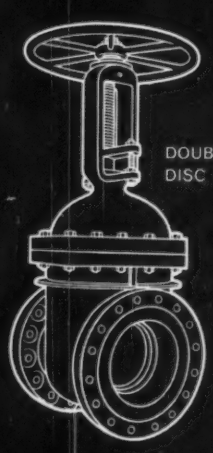
CAPOSITE Regd.

ASBESTOS INSULATION

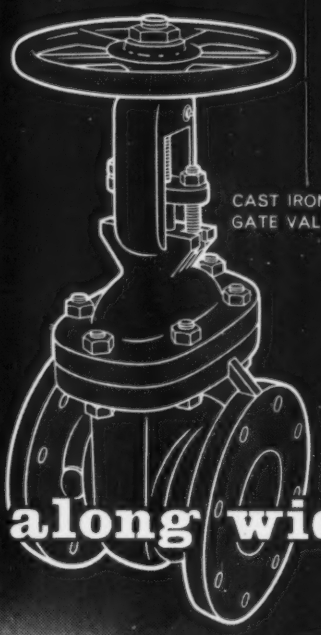
THE CAPE ASBESTOS COMPANY LIMITED, 114 & 116 PARK STREET, LONDON W1 Tel: Grosvenor 6022 Cables: Incorrupt London

Enquiries in Canada to: Cape Asbestos (Canada) Limited, 200 Bloor Street East, Toronto, Ontario
U.S.A.: North American Asbestos Corporation, Board of Trade Building, Chicago 4, Illinois

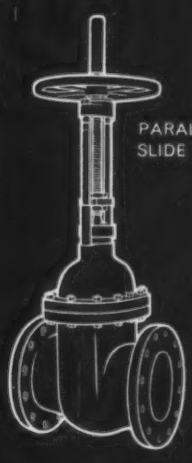
TA 10642



DOUBLE
DISC VALVE

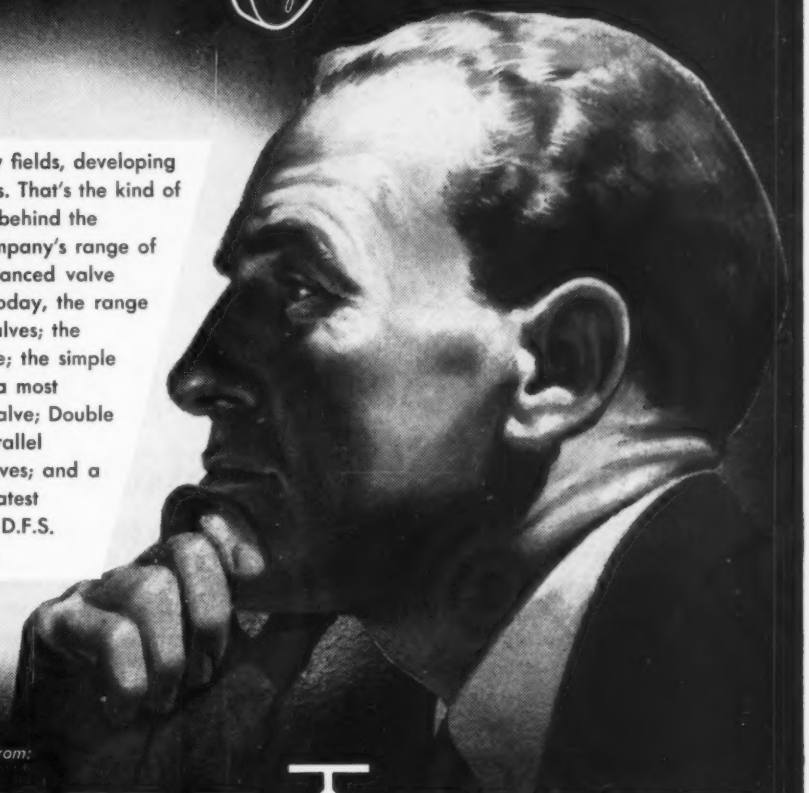


CAST IRON
GATE VALVE



PARALLEL
SLIDE VALVE

Thinking along wider lines . . .



. . . entering new fields, developing new ideas. That's the kind of look-ahead thinking behind the Triangle Valve Company's range of some of the most advanced valve designs available. Today, the range includes Alloy Steel Valves; the Cast Iron Gate Valve; the simple action Line Blind Valve; a most efficient Wellhead Valve; Double Disc C.S. Pipeline and Parallel Slide C.S. Steam Valves; and a whole series of the latest design pipe fittings in D.F.S. and malleable iron.

Full technical details and specifications from:

TRIANGLE VALVE CO. LTD.

CANBERRA HOUSE, 315-7 REGENT ST. W.1.

Tel: LANGHAM 6526-7-8 Cables: Trivalon London Telex 24-100 Works: Lamberhead Green, Wigan, Lancs, England

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SOLVENT PACKINGS

"We tested one packing after another... but only 'U.S.' could stand up,"

Says CHEMICAL PLANT SUPERINTENDENT

When a leading mid-western chemical company put their new plant into operation in 1955, they faced a problem with pump packings: To find a packing resistant to a combination of solvents, caustic and high temperature—with a minimum of shaft wear.

"We tested one packing after another on our caustic pumps," says the plant superintendent, "and found that U. S. Solvent Packing outlasted any other packing tested *by as much as 10 to 1.*"

Result: No more morale-breaking "clean-up" sessions, production is increased, personal injuries due to leaks have been reduced 75%, and there's no need for rescheduling due to breakdowns.

A "U. S." technician, of course, worked with engineers of the chemical company to develop the right packing for this particular requirement. That's part of the "U. S." service, when needed.

• • •

When you think of rubber, think of your "U. S." Distributor. He's your best on-the-spot source of technical aid, quick delivery and quality industrial rubber products.

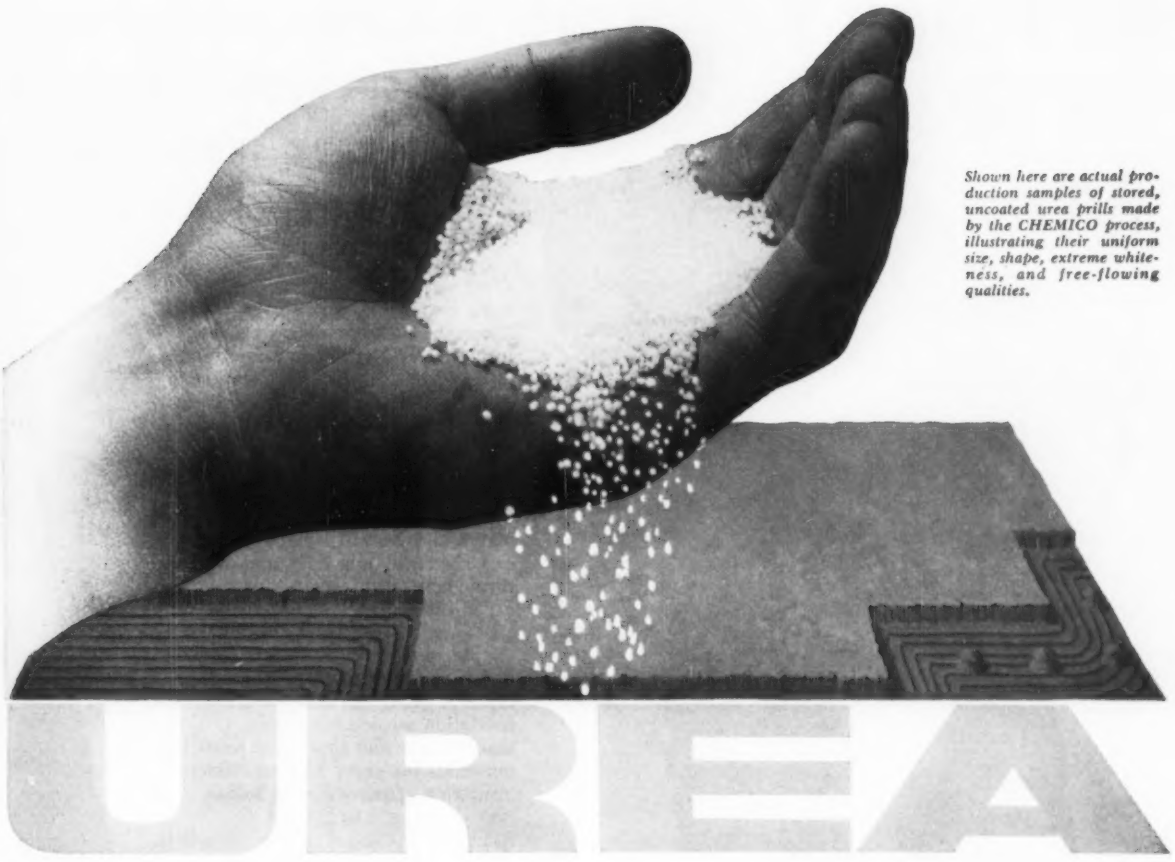
Mechanical Goods Division

United States Rubber

WORLD'S LARGEST MANUFACTURER OF INDUSTRIAL RUBBER PRODUCTS

Rockefeller Center, New York 20, N.Y. In Canada: Dominion Rubber Company, Ltd.

LOOKING FOR A GROWTH SITUATION?



Shown here are actual production samples of stored, uncoated urea prills made by the CHEMICO process, illustrating their uniform size, shape, extreme whiteness, and free-flowing qualities.

Over 1000 tons per day in production or under construction! That's the story of CHEMICO's process for making urea, one of the fastest growing chemicals in the feed, fertilizer and raw plastics fields. With its high nitrogen content, urea gives more plant food value per ton with lower handling costs. In the plastics industry, urea-formaldehyde resins are used extensively as textile and paper treating agents, adhesives, and molding compounds.

With costs a decisive factor in the urea market, the exclusive CHEMICO process offers increased efficiency, higher yields and a product with a guaranteed 46% nitrogen content. CHEMICO also offers the only commercially available, American-developed process. If you are considering the erection of a urea plant, contact CHEMICO's sales department for details on the performance-proven CHEMICO process.

CHEMICO

CHEMICAL CONSTRUCTION CORPORATION
525 West 43rd Street, New York 36, New York

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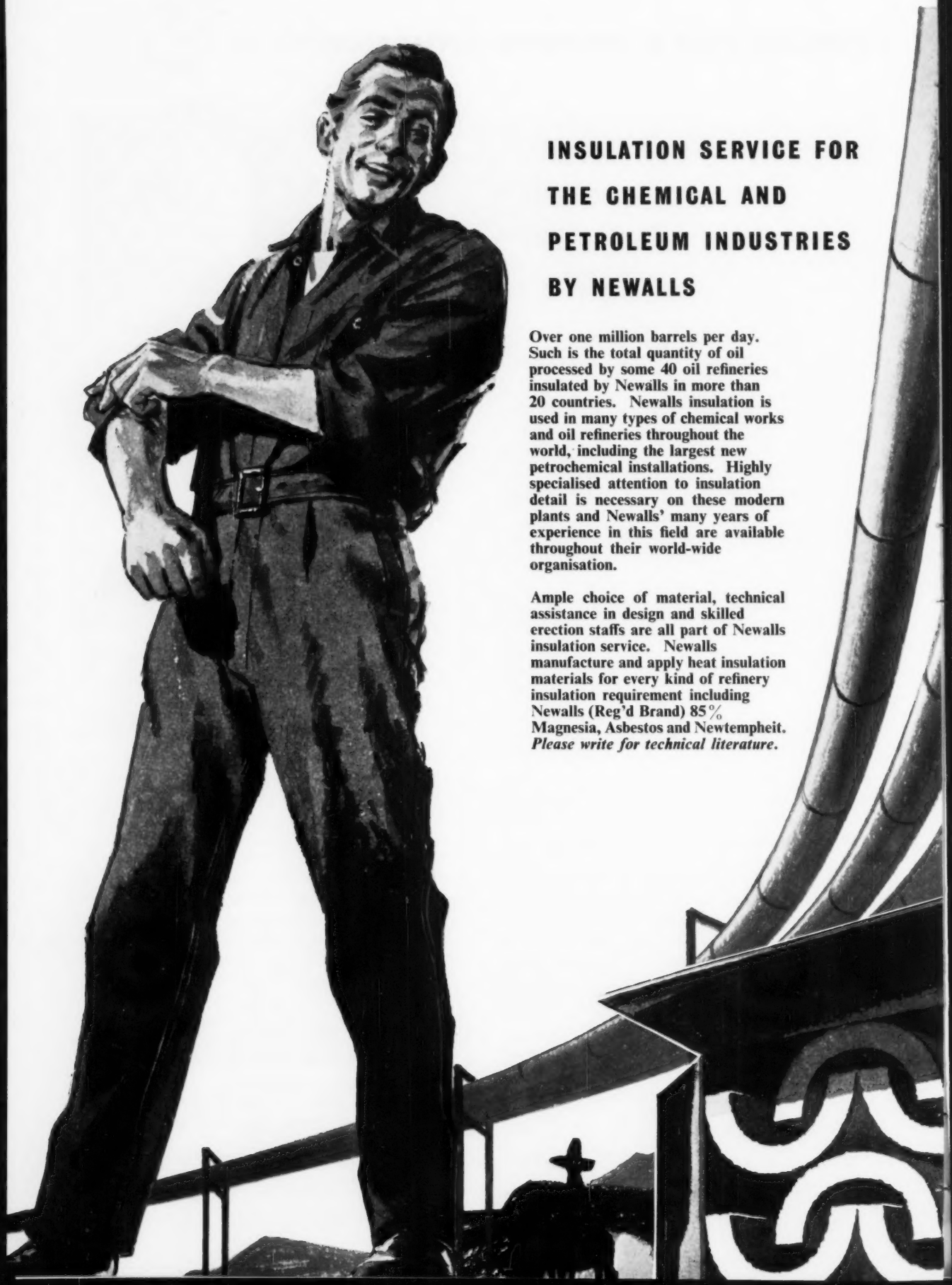


INSULATION SERVICE FOR THE CHEMICAL AND PETROLEUM INDUSTRIES BY NEWALLS

Over one million barrels per day. Such is the total quantity of oil processed by some 40 oil refineries insulated by Newalls in more than 20 countries. Newalls insulation is used in many types of chemical works and oil refineries throughout the world, including the largest new petrochemical installations. Highly specialised attention to insulation detail is necessary on these modern plants and Newalls' many years of experience in this field are available throughout their world-wide organisation.

Ample choice of material, technical assistance in design and skilled erection staffs are all part of Newalls insulation service. Newalls manufacture and apply heat insulation materials for every kind of refinery insulation requirement including Newalls (Reg'd Brand) 85% Magnesia, Asbestos and Newtempheit. ***Please write for technical literature.***

GIVE NEWTHERM YOUR TOUGHEST INSULATION ASSIGNMENT

NEWALLS (Reg'd Brand) NEWTHERM Calcium Silicate insulation is the finest answer yet to many of industry's heat insulation problems. Strong and rigid, Newtherm withstands rough handling in transit and erection, with negligible breakages even during transport to remote sites. Exceptionally light, Newtherm can be applied in difficult situations with ease — even the largest sections being manageable in one hand. Moisture resistant, Newtherm retains much of its strength even when immersed in water, does not deform, and quickly dries, leaving its strength and thermal efficiency unimpaired. Easily applied, Newtherm offers a smooth surface and straight edges for speedy fitting, and is available in many standard sizes for immediate application.

NEWALLS (Reg'd Brand)

NEWTHERM *calcium silicate insulation!*

for temperatures up to 1400°F.

NEWTHERM Calcium Silicate is manufactured solely by

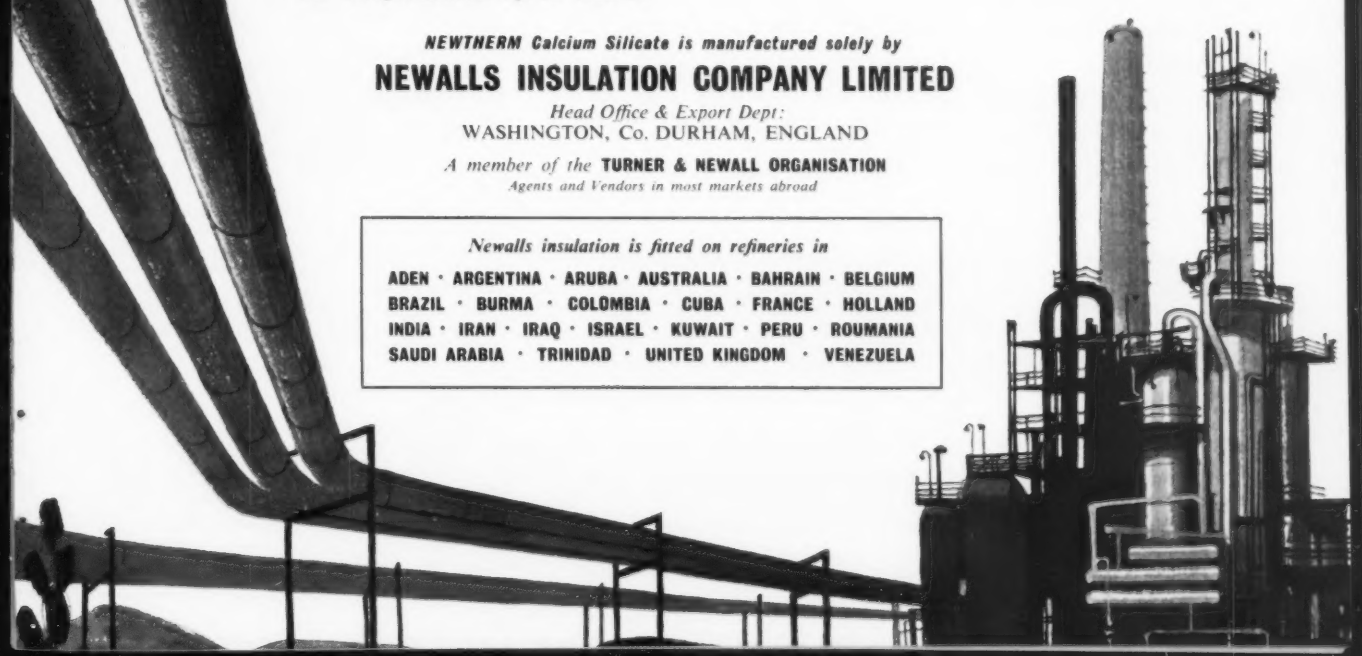
NEWALLS INSULATION COMPANY LIMITED

Head Office & Export Dept:
WASHINGTON, Co. DURHAM, ENGLAND

A member of the **TURNER & NEWALL ORGANISATION**
Agents and Vendors in most markets abroad

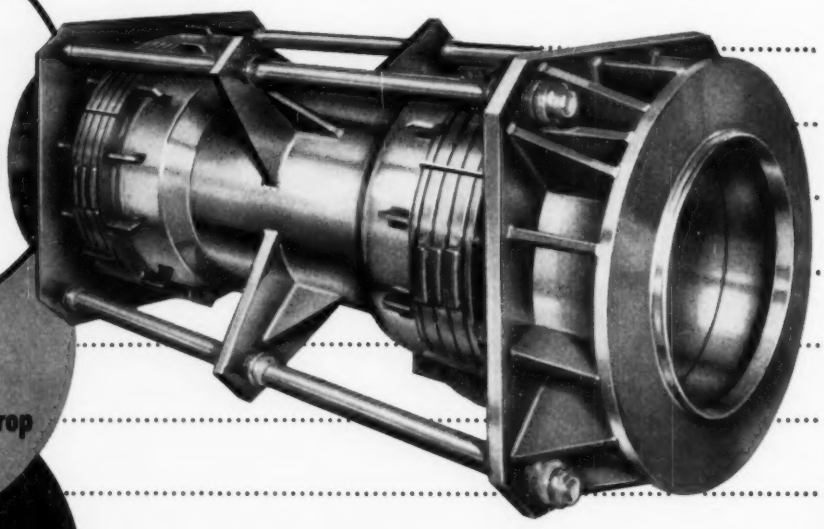
Newalls insulation is fitted on refineries in

ADEN · ARGENTINA · ARUBA · AUSTRALIA · BAHRAIN · BELGIUM
BRAZIL · BURMA · COLOMBIA · CUBA · FRANCE · HOLLAND
INDIA · IRAN · IRAQ · ISRAEL · KUWAIT · PERU · ROUMANIA
SAUDI ARABIA · TRINIDAD · UNITED KINGDOM · VENEZUELA



for Piping Protection Plus

+ lower heat loss
+ minimum space
+ lower pressure drop
+ minimum cost



Specify ADSCO

CORRUFLEX®

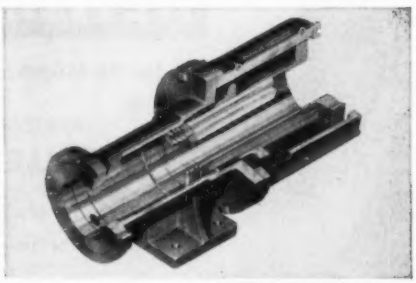
PACKLESS EXPANSION JOINTS

Adsco CORRUFLEX Expansion Joints are manufactured in sizes of 3" or larger, designed for specific line conditions. These units provide maintenance-free, trouble-free service.

Every possible combination of pipe motion can be fully compensated for – absorption of axial motion, lateral deflection and angular rotation – with one or more standard or custom-engineered CORRUFLEX packless joints built by Adsco.

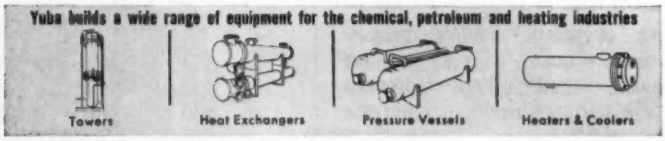
For complete engineering data write for your copy of the new CORRUFLEX Expansion Joint Bulletin, No. EJ-59-50 on your company letterhead.

Designed for a 30" diameter high pressure, high temperature service line in a southwestern aircraft and missiles engine test center, the Adsco CORRUFLEX Self-equalizing stainless steel Expansion Joint shown above is one of many custom-designed units in service.



***ADSCO** Piston-ring Slip-type Expansion Joints* are world renowned as the only joints which can be unpacked and completely repacked without shutting down line pressure. As the *only* manufacturer of both slip and packless expansion joints, Adsco recommends the proper type which is best suited to the demands of the job – your assurance of complete satisfaction, utmost economy.

Yuba builds a wide range of equipment for the chemical, petroleum and heating industries



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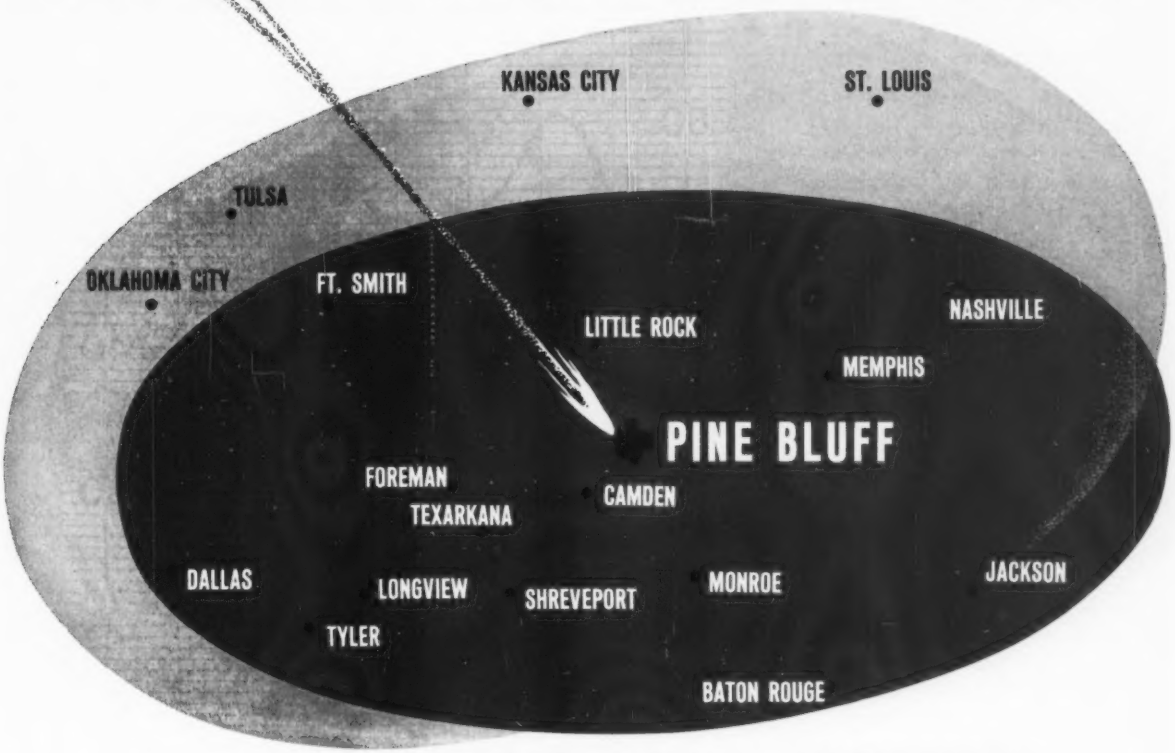
YUBA CONSOLIDATED INDUSTRIES, INC.

YUBA

Plants and Sales Offices NATIONWIDE

A NEW SOURCE OF CHLORINE & CAUSTIC SODA...



...for the CENTRAL SOUTH

Manufacturers and Marketers of

CHLORINE
and 50% - 73%
CAUSTIC SODA

Chlorine available in ton containers

PLANT:
PINE BLUFF,
ARKANSAS

GENERAL
SALES OFFICE:
SLATTERY BUILDING
SHREVEPORT, LOUISIANA

TELEPHONE 2-2141
EXTENSION -495

ARKANSAS LOUISIANA CHEMICAL CORPORATION

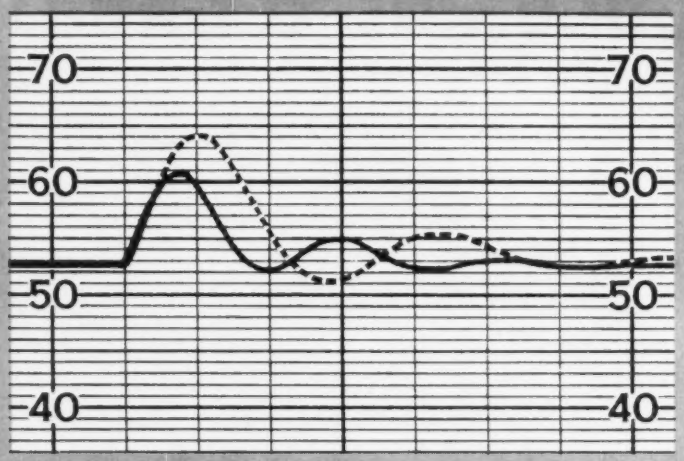
A SUBSIDIARY OF ARKANSAS LOUISIANA GAS COMPANY

For more data on advertised products, use Readers' Service Cards, last page.

86% DIFFERENCE IN CONTROL

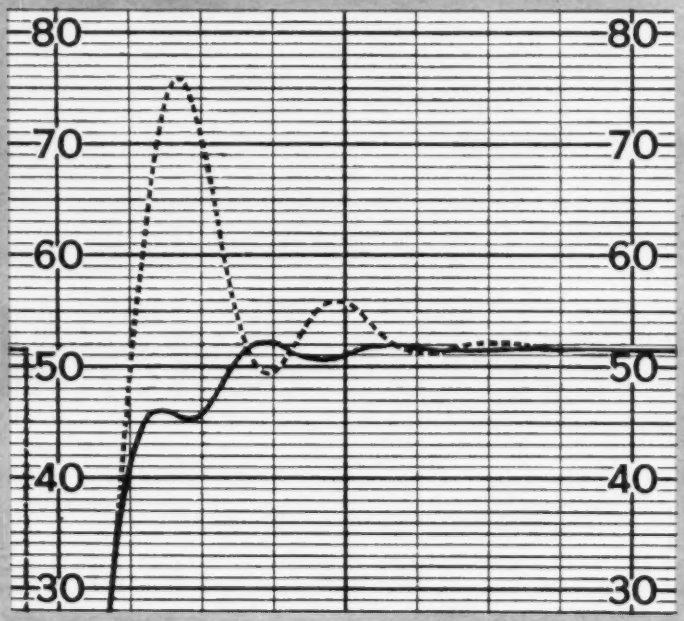
On process load change

The actual area between the recovery curve of the conventional 3-response controller (dotted line) and the set point is 86% greater than that of the Tri-Scope Controller (solid line). Quality of Tri-Scope control is that much better.



On start-up

Here is the perfect solution to your problems of overpeaking on start-up and large load changes—inherent weaknesses of proportional-plus-reset controllers. It is equally effective *at all times* whether variable is approaching control point from above or below—on start-ups, or following major process disturbances or changes in set point.



Taylor Instruments

For more data on advertised products, use Readers' Service Cards, last page.

ONLY 8% PREMIUM IN PRICE!

Taylor TRI-SCOPE* Controller performance records give overwhelming proof of its outstanding superiority

The charts at left show how the full-time use of derivative-ahead-of-reset response in the TRI-SCOPE Controller (solid line) compares with results achieved by a conventional 3-response controller (dotted line).

Quality of control is a function of the *size* of the deviation and the *time* required to regain the control point. Thus, the area under the recovery curve is a measure of quality. Since, with a conventional 3-response controller the area above the control point is 86% greater, then the TRI-SCOPE quality of control is that much better.

The additional cost for these vastly superior control qualities amounts to only 8%, when you consider the price of transmitter, recorder, valve and conventional controller, versus these same instruments and the TRI-SCOPE Controller.

It is a matter of simple economics. If your product is important enough to justify investment in a 3-response controller, 8% is a very small premium to pay for 86% difference in control. *Figure your savings over the life of the instrument!*

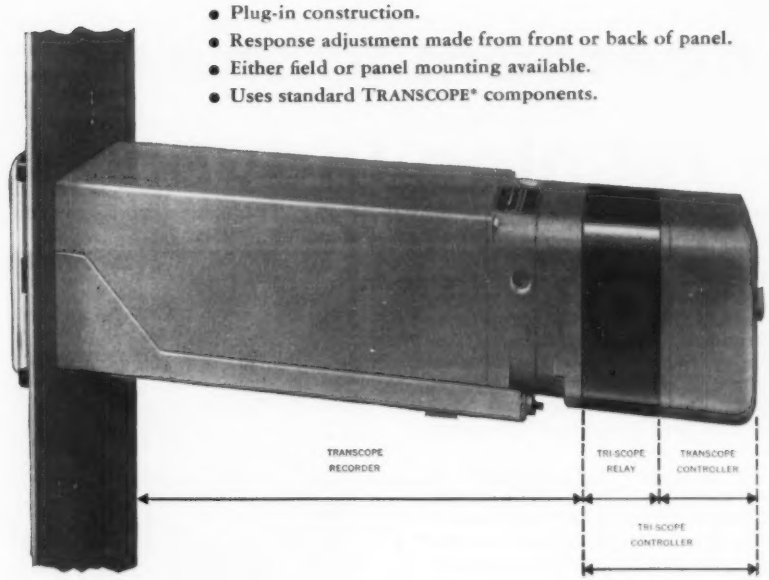
• • •

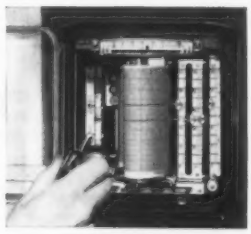
For full details of this unique new controller, see your Taylor Field Engineer, or write for **Bulletin 98332.** Taylor Instrument Companies, Rochester, N.Y., or Toronto, Ontario.

*Trade-Mark

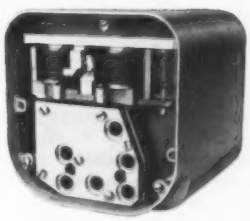
DESIGN FEATURES

- Plug-in construction.
- Response adjustment made from front or back of panel.
- Either field or panel mounting available.
- Uses standard TRANSCOPE* components.





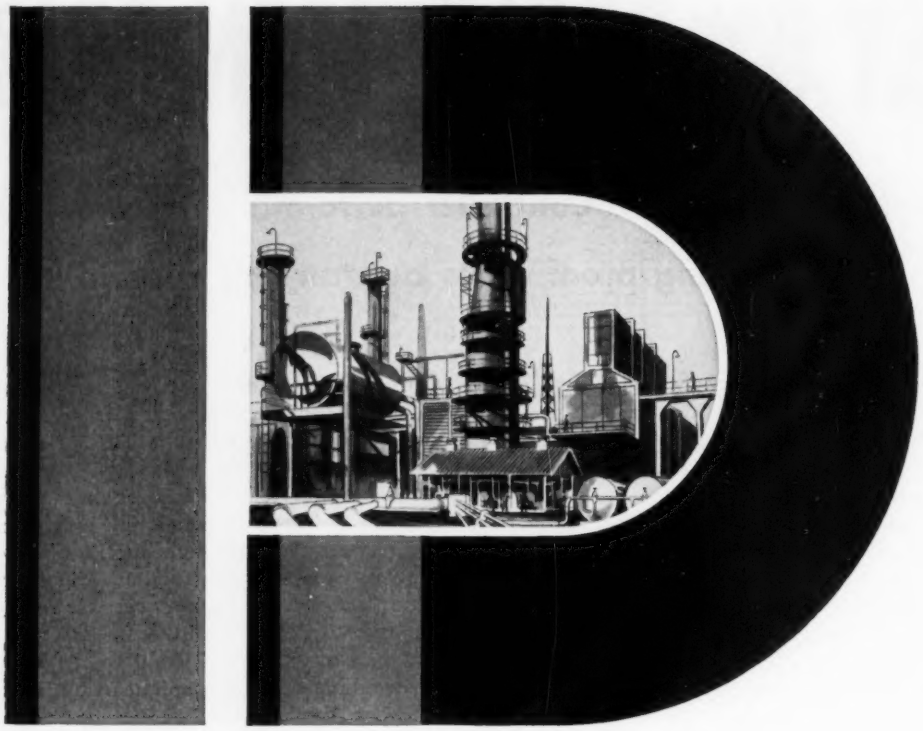
90J SERIES TRANSCOPE RECORDER



NEW 414RF TRI-SCOPE CONTROLLER

MEAN ACCURACY FIRST

For more data on advertised products, use Readers' Service Cards, last page.



+ = An important announcement to the petroleum refining industry!

Daystrom Systems and Universal Oil Products Co. announce a cooperative effort in the application of computers to the control of industrial processes.

For the first time, the facilities and engineering talents of leading process designers and computer systems specialists are combined to offer a unique service to the customer. Daystrom contributes experience and leadership in the design and manufacture of highly reliable computer equipment. Universal Oil Products Company contributes extensive experience and know-how in process design.

Two and one-half years of intensive work have yielded important progress in a pilot plant installation incorporating a Daystrom digital computer control system.

This project marked the first process control application of a solid state digital computer specifically designed for on-line operation in the process industries.

The Daystrom Systems computer completely eliminates vacuum tubes and moving parts. More than two years of field operating experience permits Daystrom to guarantee system operational availability of more than 99%. A substantial number of Daystrom computer systems have already been purchased for control and data reduction.

Daystrom has been granted license to manufacture and market control systems developed by Universal Oil Products and Daystrom Systems. Processes and techniques considered confidential by Daystrom clients will be handled by Daystrom Systems independently.

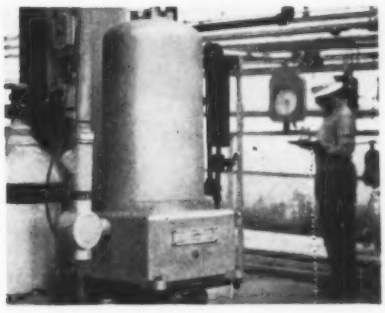
The advanced techniques and equipment developed by Daystrom Systems are available to you. For conference arrangements, write or telephone Daystrom Systems, A-108, Miramar Rd., La Jolla, Calif., GLencourt 4-0421.

INPUT CONSOLE FOR PROGRAMMING COMPUTER.

DAYSTROM SYSTEMS
DIVISION OF DAYSTROM, INC.
Reliable computer control systems

HOT GAS TEMPERATURE CONTROL

...with chromatograph reliability



When it's 2500°F inside the reactor furnace, conventional temperature-measuring elements burn out or drift without warning. To solve this problem, CEC's 26-202 Process Chromatograph can be used to verify the temperature of many processes in which the concentration of a component varies in proportion to temperature.

Precise correlation of temperature with stream purity is afforded by the chromatograph's ability to accurately measure concentration changes as small as 0.01%.

Because of the 26-202's continuous variable attenuation, readout is on a mol-percent basis. This speeds any necessary corrective action by eliminating the need for operator interpretation of chromatographic findings.

The accuracy and reliability of the 26-202 Process Chromatograph make it a true plant instrument. Corrosion-resistant stainless steel is used for all sample carrying components and an explosion-proof condulet permits safe installation of the remote-controlled analyzer unit in Class I, Group D, Division 1, hazardous locations.

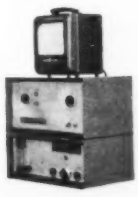
The basic 26-202 Process Chromatograph can be tailored to customers' individual application problems through addition of continuous variable attenuation, automatic stream switching, automatic zero standardization, or multiple columns with pre-cutting to reduce analysis time.

For more information contact your nearest CEC sales and service office today, or write for Bulletin CEC 1836-X44.

Analytical & Control Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS *300 N. Sierra Madre Villa, Pasadena, Calif.*

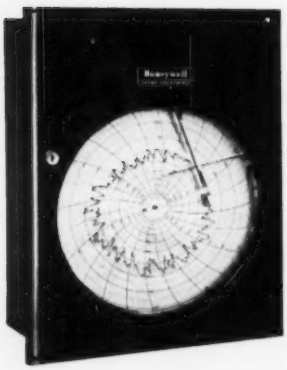
FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL



CEC's LABORATORY CHROMATOGRAPHS—Modular—consist of separate control and one or more analyzer units. 26-201A contains a thermostatted sampling valve with pre-cut column to reduce time for complex analyses. 26-203 features an adjustable temperature range from 50°C to 500°C, and filament-type detector providing high sensitivity at high temperatures. Bulletins CEC 1831-X24 and CEC 1847-X9.

Honeywell Bellows Flow Meter

HERE ARE FOUR OF MANY WAYS YOU CAN USE THE BELLOWS FLOW METER

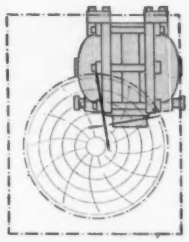


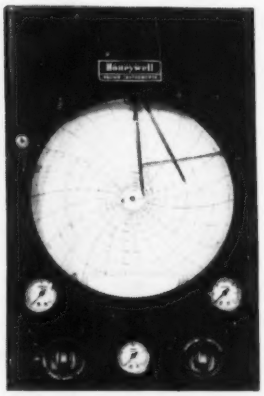
With an indicator or recorder—Indicators can be supplied with or without pneumatic transmission. Recorders can be one, two or three-pen instruments, with the second and third pens actuated by thermometer and/or pressure elements.

With a "blind" transmitter—the non-indicating differential pressure transmitter is used when indication is not required at the process and the variable is to be transmitted to remotely located instruments.

For direct measurement and control

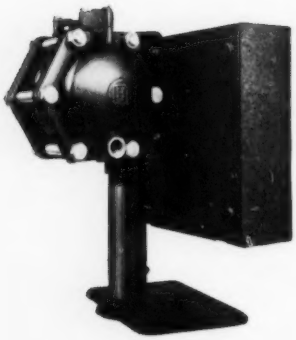
the meter is integrally mounted on indicators, indicating controllers, recorders, or recording controllers.





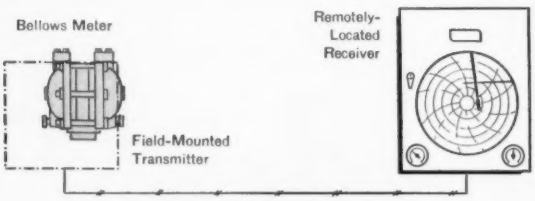
With indicating or recording controllers—All indicators and recorders can be supplied with any pneumatic control form from on-off to three-mode. Indicating controllers are also available with pneumatic transmission.

With an indicating transmitter—Scale is graduated in accordance with the flow or liquid level span of the transmitter. These transmitters are available with pneumatic control to remotely operate final control elements.



For remote measurement and control

Field-mounted transmitters, either "blind" or indicating, can be used with remotely located indicators, recorders, and controllers.



and with Tel-O-Set miniature instruments and a variety of options!

has applications unlimited

Unequaled for accuracy, stability, versatility in flow and liquid level metering

Here's the most advanced meter body available today, with advantages never before found in flow and liquid level meters. Combine the new Honeywell Bellows Flow Meter with the instruments shown on the facing page for truly superior service in metering steam, water, gas, oil and other fluids.

Some of its outstanding features:

Sensitive and accurate—Sensitive to within 0.5% of full scale . . . calibrated accuracy ±0.5% of full scale.

Leakproof—Between liquid fill and process fluid.

Automatically stabilized—Changes in meter body temperature or static pressure have no effect on output shaft position. Meter operates efficiently in ambient temperatures of minus 40°F to plus 250°F.

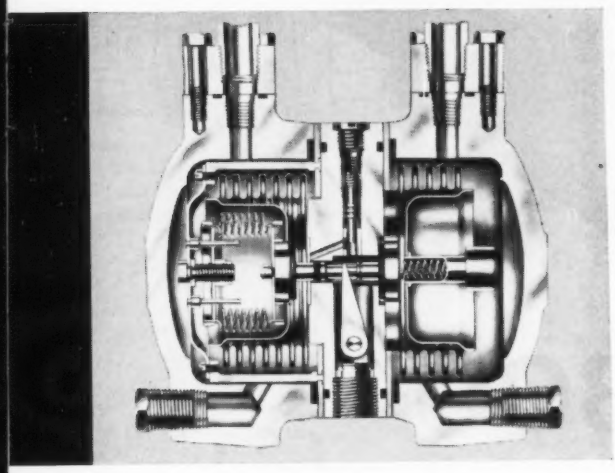
Unmatched convenience features—Including fast range changing in the field . . . connections for both horizontal and vertical piping . . . quick calibration and adjustment . . . easy cleaning and servicing.

High corrosion resistance—Seamless, stainless steel formed bellows give long, trouble-free service with virtually all process fluids.

Fast, effective damping adjustment—New type pulsation check with rectangular orifice permits essentially linear damping adjustment . . . and adjustment from outside the meter body during operation.

Models are available in many ranges, for both flow and liquid level measurement and control. Get details on *all* the features of the new Honeywell Bellows Flow Meter by calling your nearby Honeywell field engineer today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.



Transfer of liquid between opposing high and low-pressure bellows converts differential pressure measurement into motion. A torque tube assembly carries the motion outside the meter body to an instrument. Therefore, changes in differential pressure change the instrument reading.

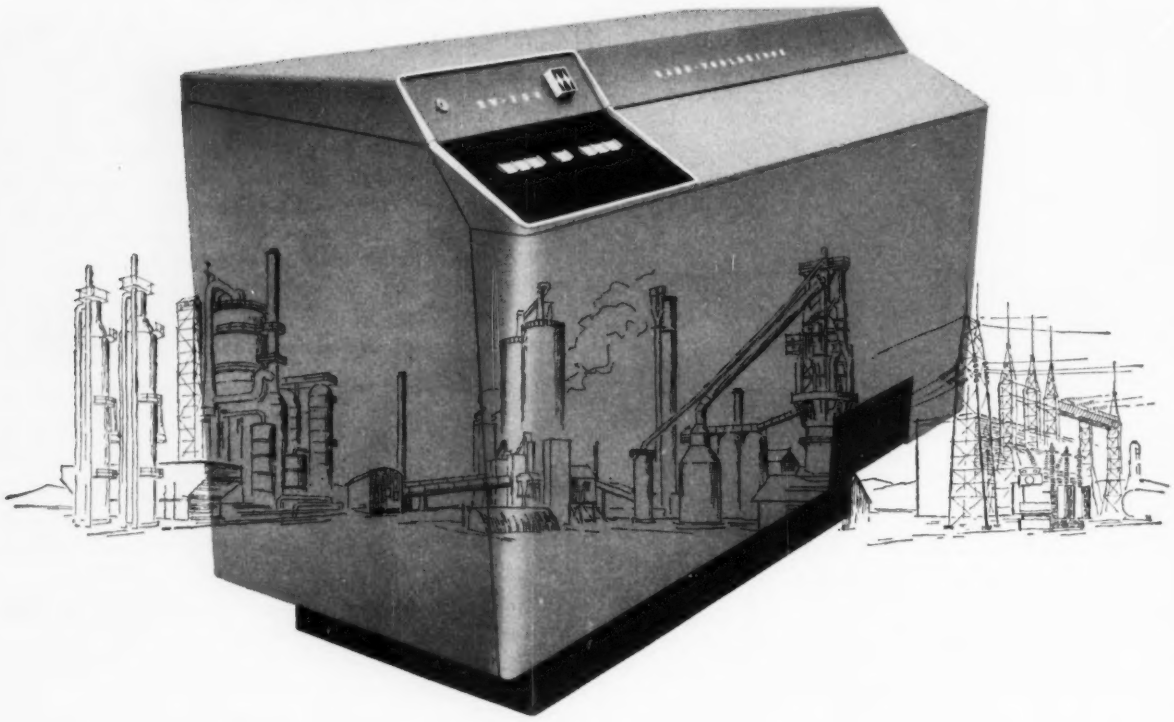
● **REFERENCE DATA: Catalog C22-1**

Honeywell

First in Control

In a Class by Itself

FOR CLOSED-LOOP CONTROL
AND AUTOMATIC DATA REDUCTION



The RW-300

DIGITAL CONTROL COMPUTER

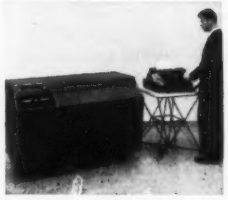
OPERATING SYSTEMS incorporating the RW-300 for on-line control and data reduction are demonstrating these tangible benefits: *reduced costs, increased output, improved quality.*

HIGH RELIABILITY, inherent in the advanced design of the RW-300, is being proven by thousands of hours of dependable operation.

SYSTEMS ENGINEERING staff, experienced in the analysis of complex control and data reduction problems, is assisting industry with applications of the RW-300 in chemical, petroleum, steel, cement, electric power, and other fields.

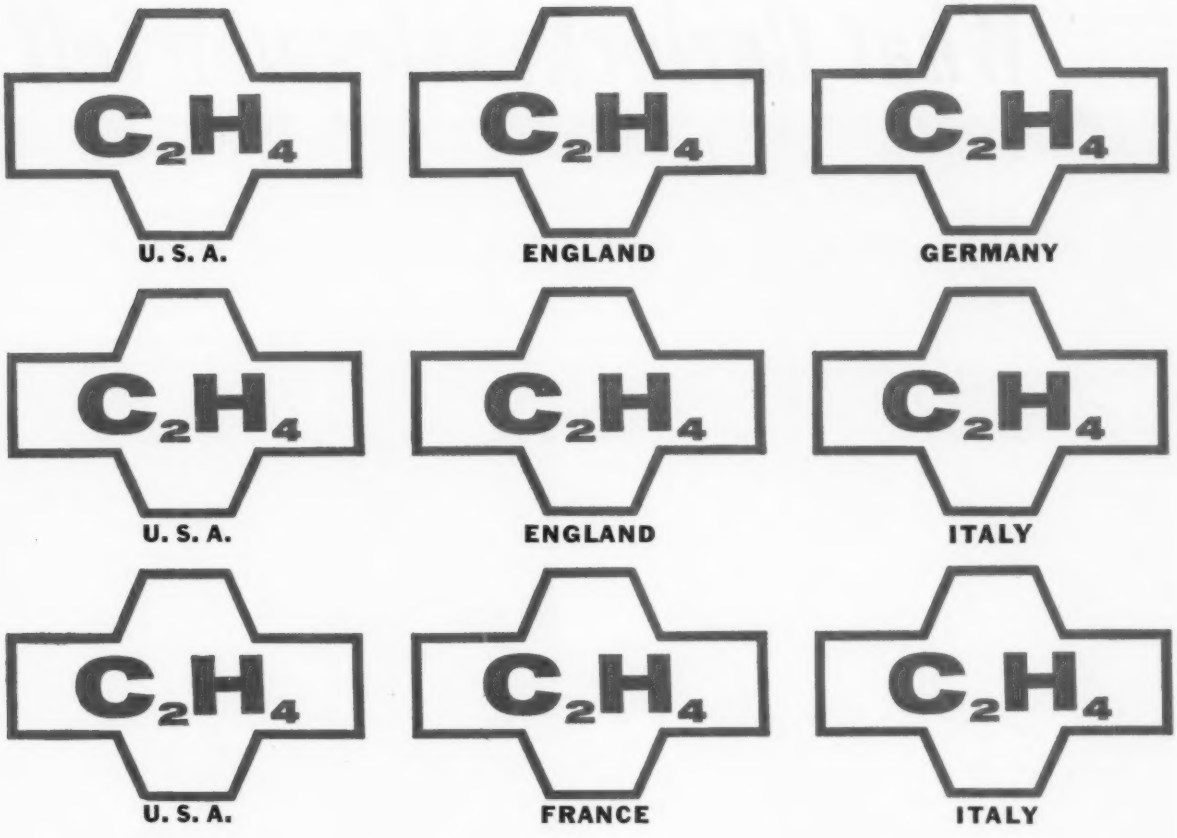
NATION-WIDE SERVICE organization is providing skilled maintenance for this completely developed, production engineered, and thoroughly tested piece of *industrial* equipment.

For further information, call or write: Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, P.O. Box 90067 Airport Station, Los Angeles 45, California, OSborne 5-4601.



THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

a division of ***Thompson Ramo Wooldridge Inc.***



A BILLION-POUND BACKGROUND in Engineering Ethylene Plants

Leading oil and chemical companies on both sides of the Atlantic testify to the Kellogg Organization's ability to engineer ethylene manufacturing and recovery plants. The twelve for which Kellogg has been responsible to date represent an annual capacity in excess of 1,050,000,000 pounds!

Utilizing its high-efficiency steam-pyrolysis process, and many unique design features, Kellogg is unusually equipped to engineer and build economically sound plants for producing high purity ethylene and other valuable olefins from various feed-stocks.

Typical Kellogg design innovations for ethylene recovery systems are: (1) a heat pump circuit which permits tower top reflux to be provided by condensing overhead vapors while doing tower reboiler duty; (2) an auto-refrigeration system based on a Joule-Thompson or Isentropic expansion of tower overhead vapors; and (3) an intermediate condenser and reboiler on the demethanizer to minimize refrigeration requirements.

When considering ethylene plants, call on the billion-pound background of The M.W. Kellogg Company.

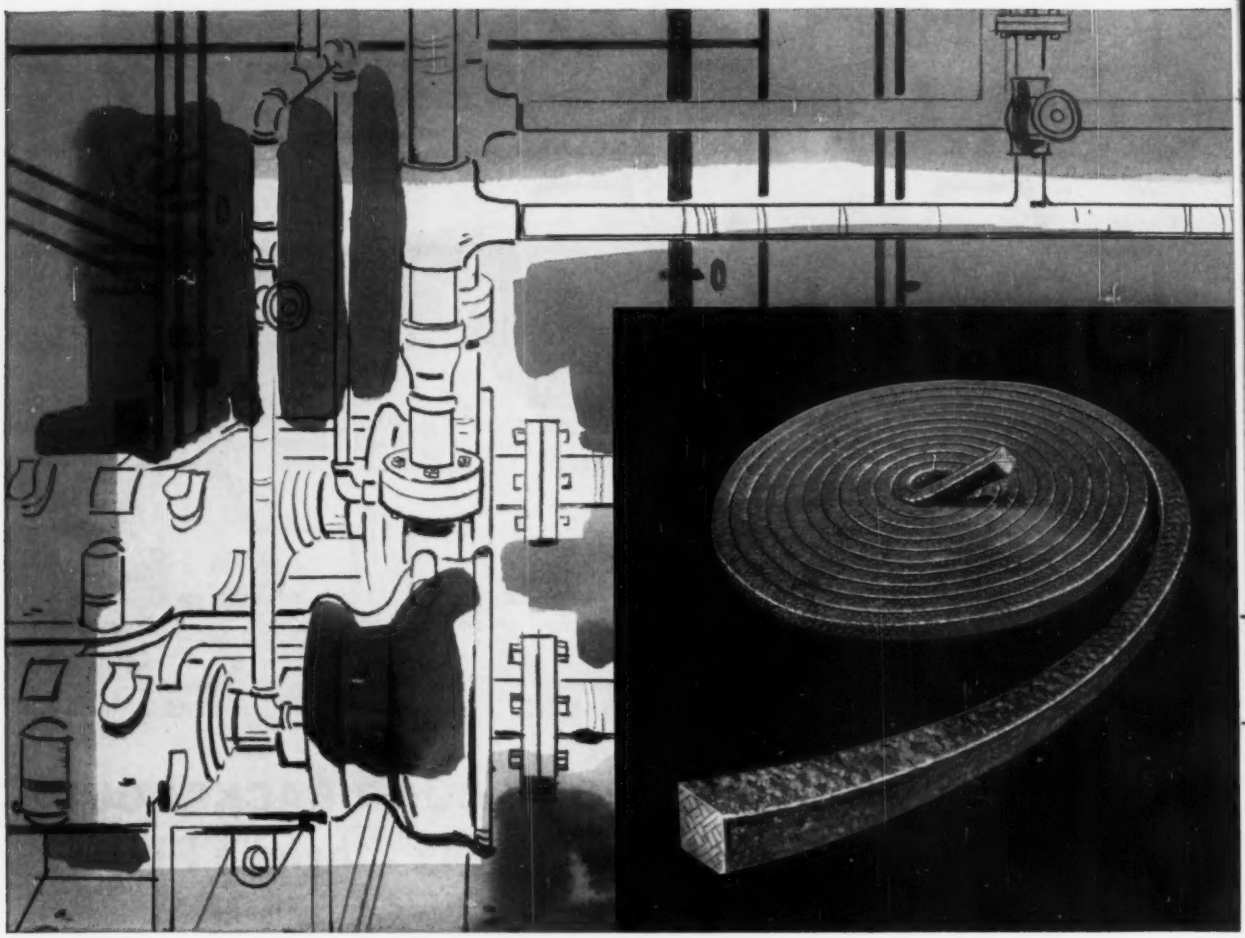
THE M. W. KELLOGG COMPANY
A Subsidiary of Pullman Incorporated
711 Third Avenue, New York 17, N. Y.

The Canadian Kellogg Company, Limited, Toronto • Kellogg International Corporation, London • Kellogg Pan American Corporation, Buenos Aires • Societe Kellogg, Paris • Companhia Kellogg Brasileira Rio de Janeiro • Compania Kellogg de Venezuela, Caracas

M KELLOGG W

For more data on advertised products, use Readers' Service Cards, last page.

What Garlock Salesmen tell



"LATTICE-BRAID* TEFLON† PACKING IS YOUR BEST BET FOR PUMPS AND ENGINES"

"LATTICE-BRAID TEFLON is just about perfect for oil, gas and petro-chemical service—it's a strong, long-lasting, chemically-inert packing that reduces maintenance and downtime. Let me show you what I mean.

"With LATTICE-BRAID packing, each strand passes diagonally through the body of the packing at a 45° angle. This through-and-through braiding makes a completely unified structure of *greater strength*. Ordinary braided packings become worthless once the single outer cover is worn through. On LATTICE-BRAID, there is no single outer cover; thus, the braiding holds together far beyond the limits of other packings. This, obviously, results in *longer life*.

"On top of this, you have the advantage of TEFLON. It is completely unaffected by the strongest acids, solvents, and alkalies. Co-efficient of friction is extremely low, and it will withstand temperatures ranging from −90° F to +500° F.

"One customer repacked every two weeks on a solvent recovery pump application. He changed to LATTICE-BRAID TEFLON over two years ago and hasn't repacked since."

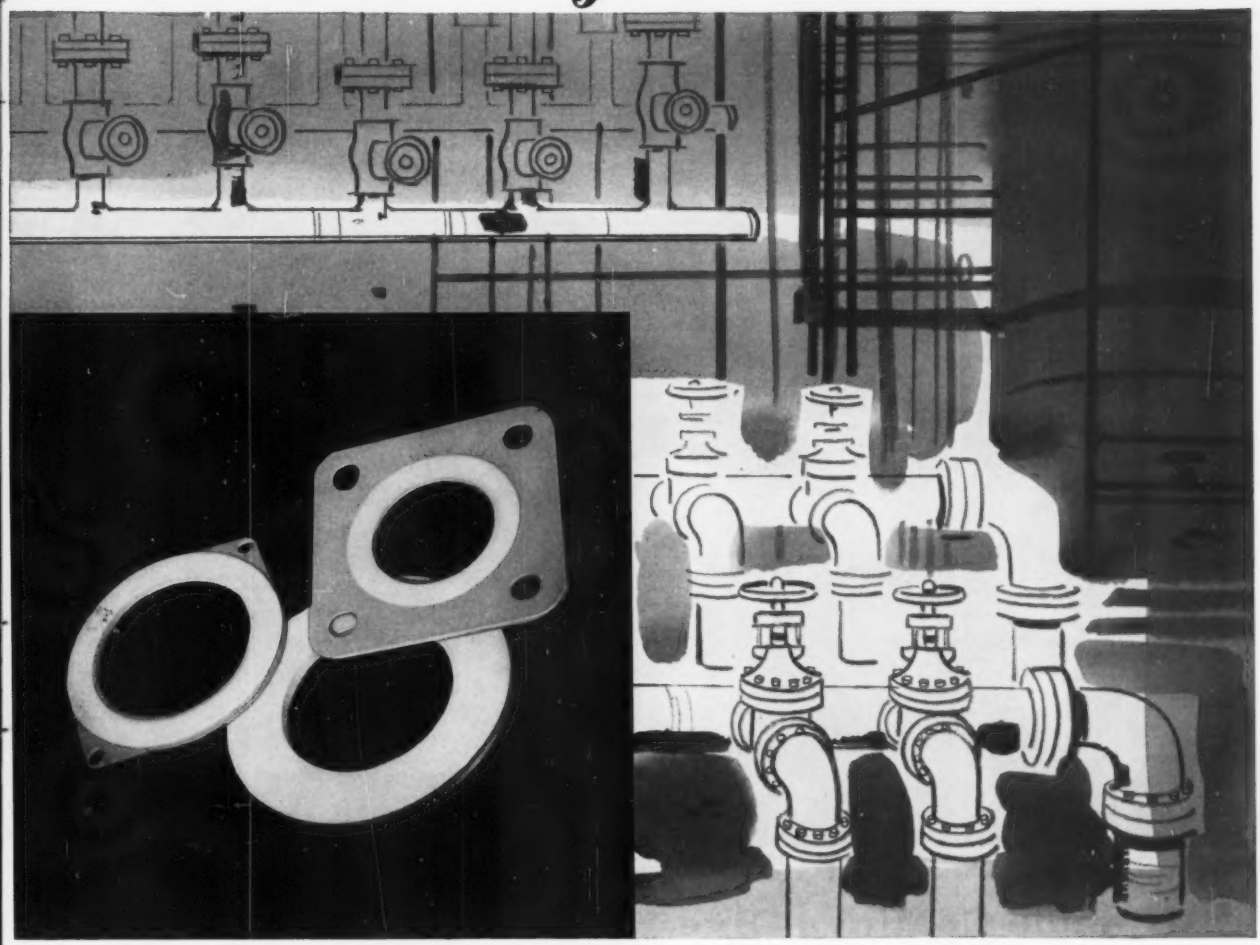
Garlock can furnish you with LATTICE-BRAID packing in a variety of sizes and styles depending on what you need. If you have a particular problem, call our sales office in your area. Or, you can write for further information. Ask for Catalog AD-131.

*Registered Trademark
†DuPont Trademark

GARLOCK

Packings, Gaskets, Oil Seals, Mechanical Seals,
Molded and Extruded Rubber, Plastic Products

Petroleum Engineers



"BUY LONG-LASTING TEFLON GASKETS FOR PIPING, FLANGES AND FITTINGS"

"With TEFLON jacketed gaskets the outstanding advantage is that you get the fine qualities of TEFLON without sacrificing resiliency and deformability. This, of course, is extremely important on your glass-lined steel piping and process equipment, light metal flanges, and glass pipe flanges and fittings.

"The first step in choosing the proper gasket is to select the type which will work best for you. TEFLON-jacketed gaskets come in four basic designs:

"Once this design is chosen, it's a matter of considering the filler material and thickness. For example, for high pressures, a corrugated stainless steel filler is suggested. Where the application is for glass-lined steel connections with low bolt loads, a rubber filler should be sandwiched between woven asbestos cloth. We offer many different types of fillers, depending on what you need—rubber, asbestos, cork, etc."

Why not let our representative in your area help you select the right gasket design? Discuss your problem with him or write for our Catalog AD-154.

A: Slit Envelope. Teflon stock slit from outside diameter to within ⅛" of inside diameter.

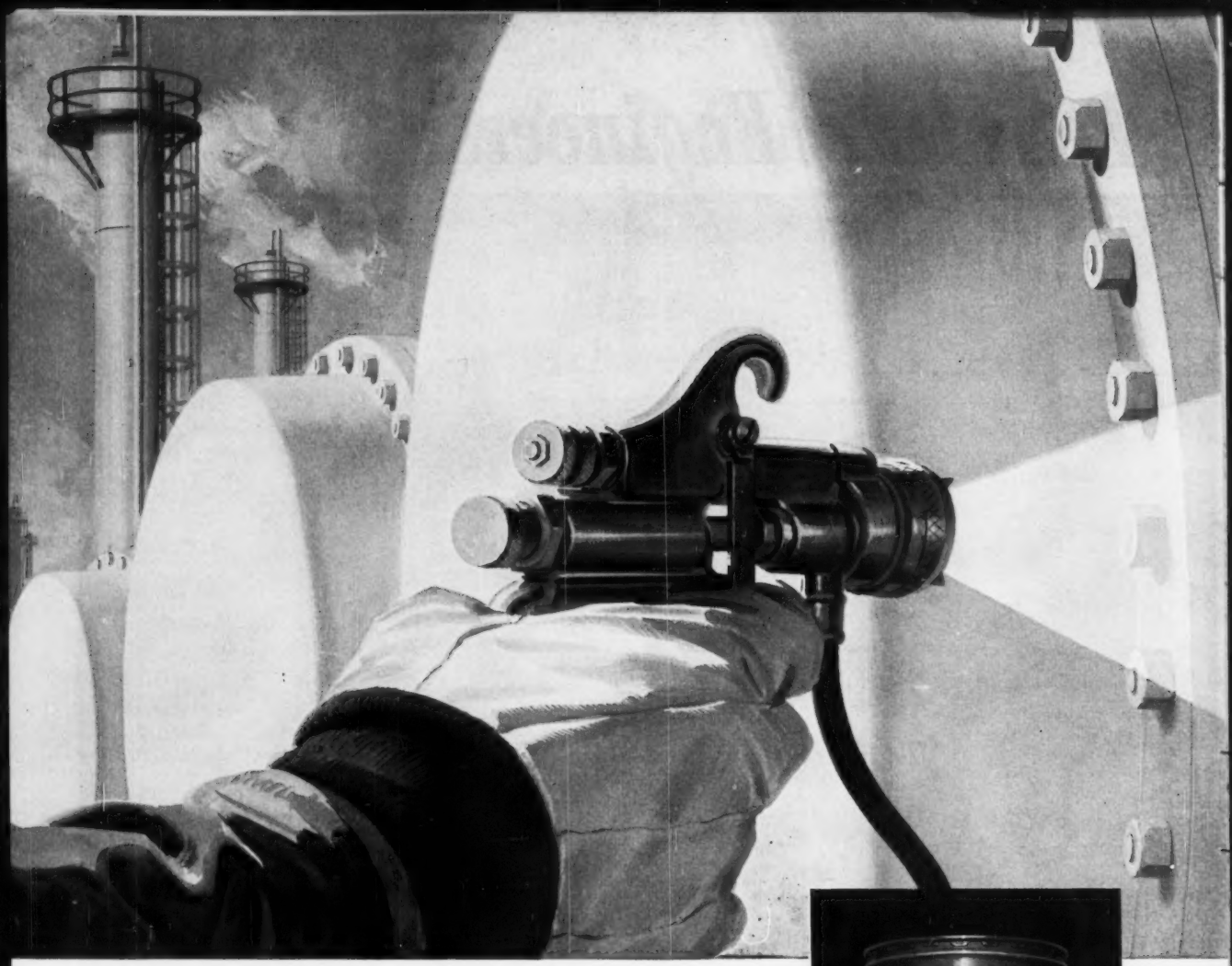
B: Milled Envelope. Teflon stock machined from outside diameter to within 1/32" of inside diameter. Gasket I.D. does not interfere with process flow.

C: Formed Shield for large diameters and irregular opening such as elliptical manholes.

D: Double Jacket. Two jackets overlapping to protect O.D. as well as I.D. For glass-lined steel nozzles.

THE GARLOCK PACKING COMPANY, Palmyra, N. Y. For Prompt Service, contact one of our 30 sales offices and warehouses throughout the U. S. and Canada.

CANADIAN DIVISION: The Garlock Packing Company of Canada Limited
PLASTICS DIVISION: United States Gasket Company



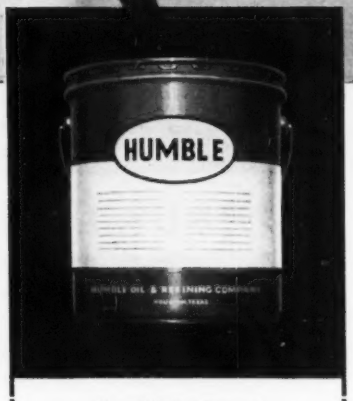
Humble Coatings Give You Three-Way Reduction in Maintenance Costs!

Humble coatings last six months to a year longer than most other paints. You save *two* ways — on paint and labor. The *third,* and most important, way you save is this: you get better protection, which means longer life for expensive equipment.

Humble coatings contain rust-preventing ingredients that not only provide surface protection, but also neutralize any corrosive elements that may penetrate the surface protection and attack the metal. These coatings were specially developed to give maximum protection in refineries and chemical plants where strong acids, alkalis and salt sprays produce severe corrosive conditions.

Without cost or obligation, one of Humble's trained engineers will make a thorough study of your needs and recommend a complete painting program for you. Call your nearest Humble representative, or phone or write:

HUMBLE OIL & REFINING COMPANY
Consumer Sales, P.O. Box 2180,
Houston 1, Texas



Humble's line of coatings includes —

- RUST-BAN ®
- Epoxies
- Phenolics
- Tank coatings
- Vinyls
- Acrylics
- Enamels
- Hot surface coatings
- Interior and exterior emulsion-type paints

HUMBLE

If you have the problem of increasing octane rating and production in your existing equipment, investigate the unique performance of Sinclair-Baker RD 150 Platinum Reforming Catalyst. Its efficiency in producing *important yield increases at high octane levels* is a matter of record. The long period of RD 150 operation is unmatched by any other catalyst . . . further, *it is regenerative in situ!* Cost is sharply reduced to lowest level.

Higher octane levels and longer catalyst life... with existing equipment ...merely by replacing with Sinclair-Baker RD 150 Platinum Catalyst

ENGELHARD INDUSTRIES, INC.

EXECUTIVE OFFICES:

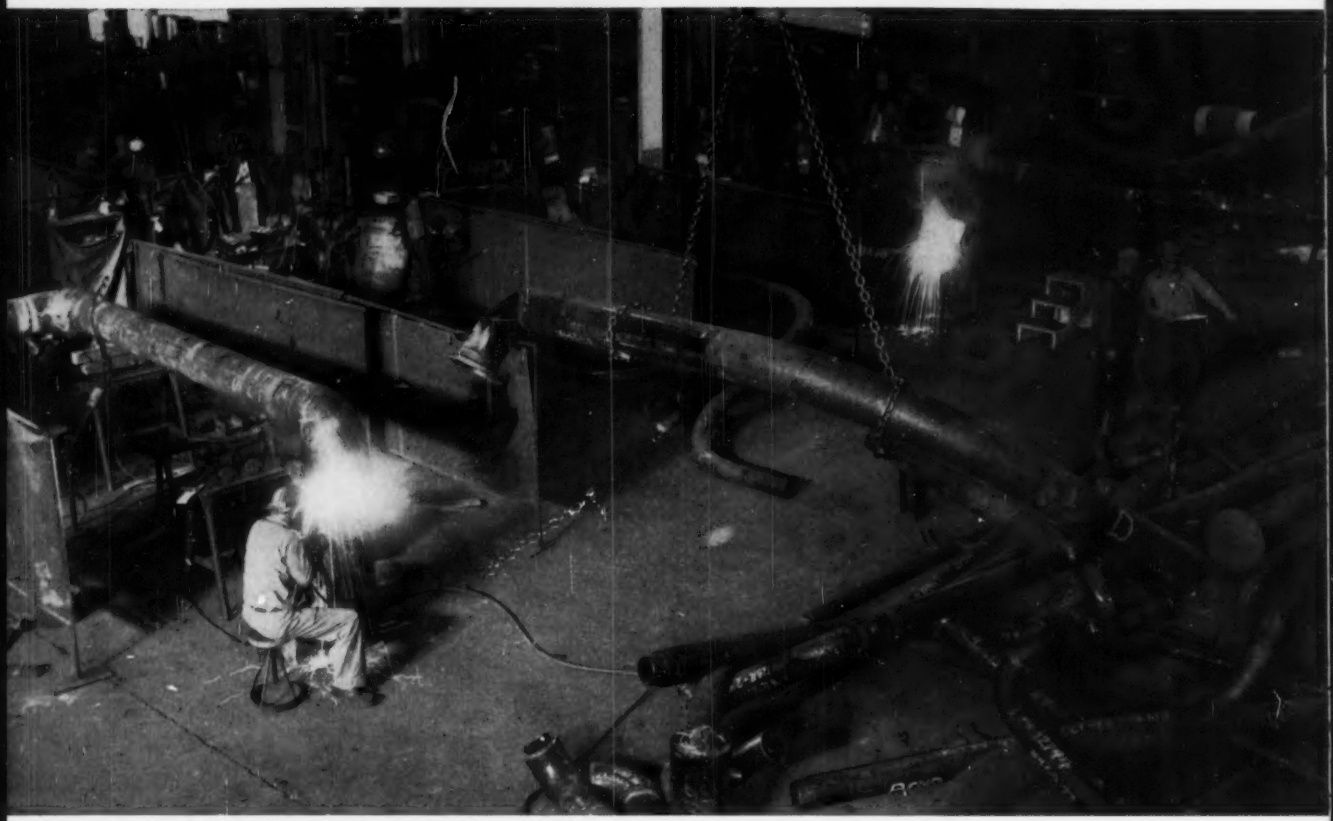
113 ASTOR STREET • NEWARK 2, NEW JERSEY

CHEMICAL DIVISION

DOMESTIC DIVISIONS: AMERICAN PLATINUM & SILVER DIVISION, AMERSIL QUARTZ DIVISION, BAKER CONTACT DIVISION, BAKER DENTAL DIVISION, BAKER SETTING DIVISION, BAKER PLATINUM DIVISION, CHEMICAL DIVISION, EAST NEWARK INDUSTRIAL CENTER, HANOVIA LAMP DIVISION, HANOVIA LIQUID GOLD DIVISION, IRVINGTON-BAKER REFINING DIVISION, D. E. MAKEPEACE DIVISION, NATIONAL ELECTRIC INSTRUMENT DIVISION, RESEARCH AND DEVELOPMENT DIVISION, H. A. WILSON DIVISION. COMPANIES ABROAD: ENGELHARD INDUSTRIES OF CANADA, LTD. TORONTO, ENGELHARD INDUSTRIES OF QUEBEC, LTD. MONTREAL, ENGELHARD INDUSTRIES, LTD. LONDON, ENGELHARD INDUSTRIES A. G. ZURICH, ENGELHARD INDUSTRIES PTY., LTD. MELBOURNE, SOCIEDAD SURAMERICANA DE METALES PRECIOSOS S. A. BOGOTA, INDUSTRIE ENGELHARD S. P. A. ROME, ENGELHARD INDUSTRIES OF SOUTHERN AFRICA, LTD. JOHANNESBURG. ASSOCIATED COMPANIES: ACME TIMBER INDUSTRIES LTD., SOUTH AFRICAN FOREST INVESTMENTS LTD., SOUTH AFRICA, AZOPLATE CORPORATION, CHARLES ENGELHARD, INC., NUCLEAR CORP. OF AMERICA, INC., U.S.A.

For more data on advertised products, use Readers' Service Cards, last page.

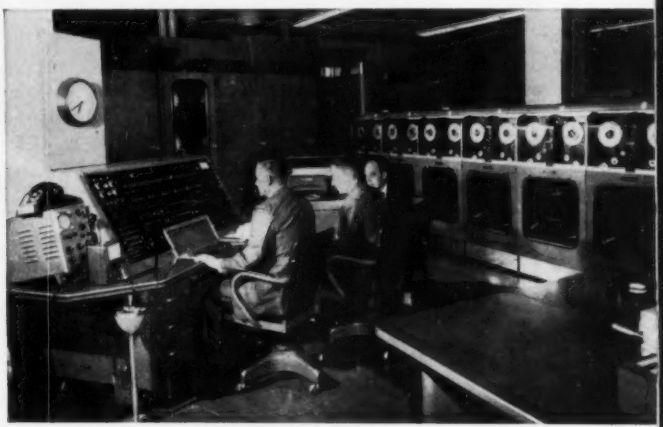
How Blaw-Knox cuts your power piping costs



121,000 square feet of space at your service. Power piping facilities at Pittsburgh include 56,000 square feet of plant area and an additional 65,000 square feet for exterior storage. An additional new plant is located on a 15-acre site in Jackson, Mississippi.

Your job is under the personal supervision of an experienced engineer, who follows your project from beginning to end. Your piping is handled with the most modern equipment for welding, heat treating, and bending. Fabricating techniques, proven by rigid testing, are used.

New product development. Blaw-Knox pioneered the enclosed type of functional spring hanger as part of their complete line of hangers for supporting any piping system. Here a group of hangers individually designed for a project is factory checked to assure fast field erection.



Stress calculation cut from months to a day . . . with pace-setting engineering. An exclusive Blaw-Knox method uses an electronic computer for automatic computation with no limitation on the complexity of system. Full accuracy, with tremendous savings in time and cost. Write for details.

BLAW-KNOX

BLAW-KNOX COMPANY
Power Piping Division
829 Beaver Avenue, Pittsburgh 33, Pennsylvania

"But officer, we were only hurrying to pick up his P.F.I. STANDARDS!"

SEND COUPON BELOW FOR THESE P.F.I. STANDARDS

1 Machining Backing Rings for Butt Welds
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3 Linear Tolerances Bending Radii
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6 Built-up Weld, Metal Bosses
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8 Preheat-Postheat Before, After Welding
9 Arc-Welding Dissimilar Ferritic Steels
10 Stress Relieving Practices

The traffic officer could be more sympathetic, but he's heard all kinds of "fabrications" . . . unfortunately, he doesn't understand the many problems of pipe fabrication or he would know all about the value of P.F.I. Standards.

These P.F.I. Standards are packed with vital data on the design, the fabrication and erection of high pressure and high temperature piping used by all industry. However, these technical bulletins do not explain the many advantages of shop fabrication.

Remember, shop fabrication by the companies responsible for the development of P.F.I. Standards is your only real assurance of meeting the most exacting requirements of piping, whether it's welded, bent, coiled or vanstoned . . . in any metal as a component or a complete assembly. Write for all ten P.F.I. Standards or indicate in the coupon below which ones could be helpful to you.

P.F.I.
THE PIPE FABRICATION INSTITUTE

THE PIPE FABRICATION II STITUTE

Devoted to the Technical and Economic Problems in Piping

ONE GATEWAY CENTER, PITTSBURGH 22, PA.

Please send me the P.F.I. Standards indicated 2PR

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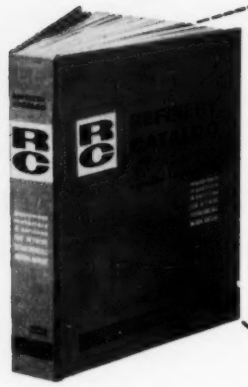
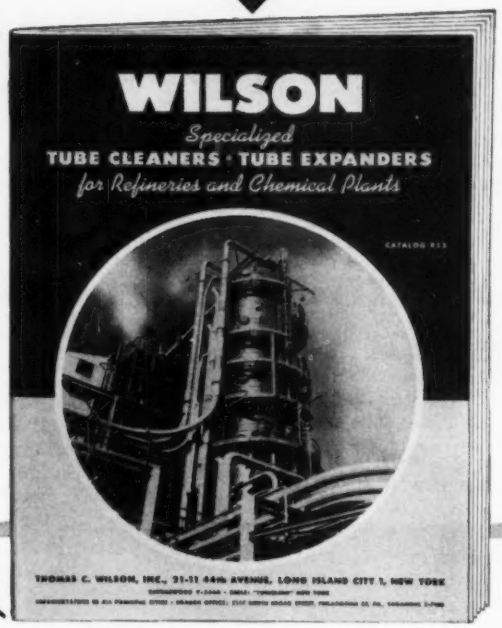
Look for it here

12 pages of helpful selection data

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for Refineries and Chemical Plants
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Here's what you will find in this Wilson Catalog

- **Air Motors** *for straight tubes*
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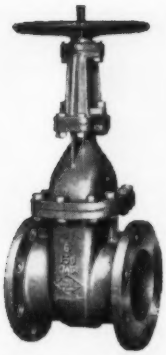


In this **Split Wedge Gate**

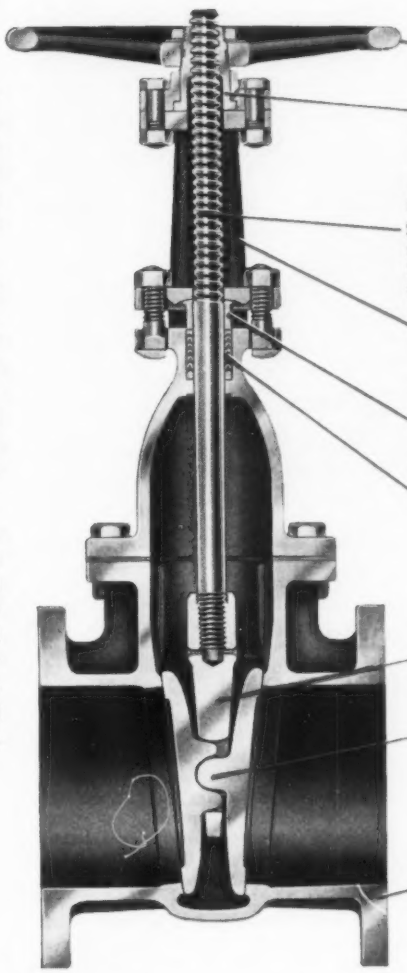
you can see why it pays to

Specify JENKINS for STAINLESS STEEL Valves, too

This picture shows the many points of excellence in the design and construction of Jenkins Fig. 1327 Split Wedge Stainless Steel Gate Valves. Compare them with any valve you know. You'll conclude that it's hard to beat Jenkins at making valves, no matter what the material.

But no picture can show the quality of the castings . . . the precision machining . . . the rigid inspection and testing that have gone into this valve. All of these are as important as design and metal alloys in assuring long, dependable, economical valve service. And, all of them are up to the peak standards for which Jenkins has been known for almost a century.

SEND FOR NEW CATALOG of Jenkins Stainless Steel Valves. You'll find in it the patterns you want, in a choice of alloys that satisfy the requirements of practically all corrosive services. Also, you'll see that these Jenkins valves meet valve industry specifications and the high standards established by the leading users of stainless steel valves. Jenkins Bros., 100 Park Avenue, New York 17.



WHEEL of high strength malleable iron designed for firm grip and easy operation.

YOKE BUSHING, easily renewable. Made of bronze, for ideal thread engagement with stainless steel spindle, to prevent seizing or galling of spindle threads. Bushing of stainless steel is optional.

SPINDLE has long thread bearing surfaces with correct lead for easy, tight closing. Screws into wedge carrier, then secured by a stainless steel pin.

YOKE BONNET has liberal space between yoke arms for easy access to packing box. Precision machined flange face assures uniform contact with gasket for a tight body-bonnet joint.

GLAND consists of two pieces — gland flange and gland follower — eliminates binding of follower in case gland bolts are tightened unevenly.

PACKING of Chevron-type Teflon in large packing box prevents leakage. Only a minimum load is required on gland, extending service life of packing.

WEDGE CARRIER connects wedge to spindle and raises or lowers it. Husky in size to stand any operating strains.

SPLIT WEDGE is the ball-and-socket design which automatically adjusts to the tapered seating surfaces for positive shutoff. The discs, revolving freely in the wedge carrier, produce a self-cleaning action on seating surfaces and reduce possibility of galling and seizing.

BODY —Through-port design for full, free flow. Ample wall thickness and good design provide extra strength to withstand stresses. End flanges conform to M.S.S. specs.

JENKINS
LOOK FOR THE JENKINS DIAMOND
VALVES

Sold Through Leading Distributors Everywhere

JENKINS BROS., 100 Park Avenue, New York 17, N. Y.

☐ Send the new stainless steel valve catalog

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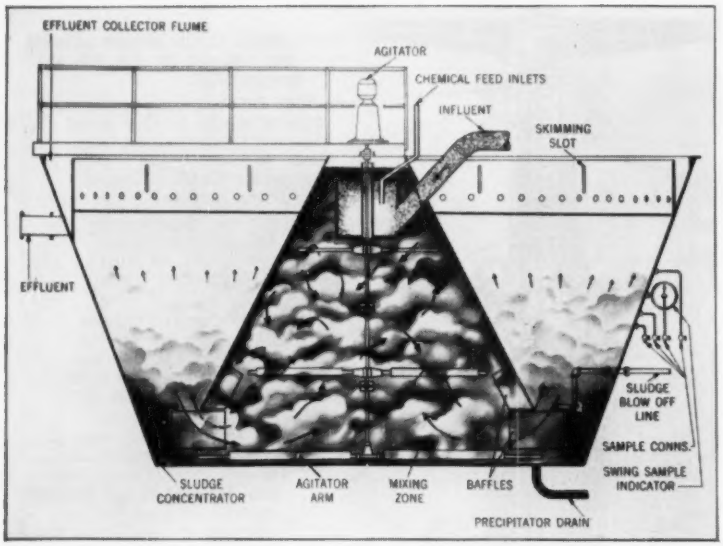


FLUIDICS AT WORK

How U. S. Rubber separates 15 to 25 tons of ashes a day

When you dump water into the Detroit River, that water has to be as clear as the river water itself.

That's why U.S. Rubber installed a 300 GPM Permutit Precipitator in the ash handling system of its Detroit plant two years ago.

Operating without coagulants or other chemicals, this unit handles varying loads, removing from 15 to 25 tons of ashes each day, delivering a clear effluent that meets the municipal code.

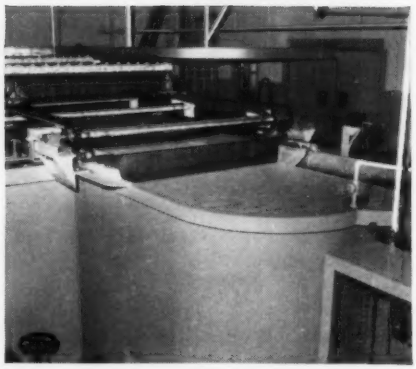
In General

Cost is low. Permutit Precipitators are so efficient that they cut processing time by 50% to 75%. And they usually need only about 50% as much ground space as conventional types of separators.

How it works. Raw water constituents and chemicals (if required) react in the presence of large quantities of previously formed sludge in the Precipitator's mixing zone. Agitation and water flow keep the sludge blanket in constant suspension, trapping incoming particles (as illustrated).

As the cross-sectional area in the sludge filter zone gets larger, the upward flow rate of water slows down and particles separate at a defined level. The water coming out of the blanket zone is completely clear and ready for re-use or disposal.

Information. If you need advice about any type of water treatment . . . based on experience with all basic types of solids separation equipment — coagulation, settling, flotation, centrifuging, evaporation, and ion exchange—Circle "A" on the coupon.



FLUIDICS AT WORK

International Harvester's Fort Wayne Works cuts oil to less than 10 ppm in waste waters

International Harvester's plant at Fort Wayne, Indiana, discharges waste waters through a storm sewer that empties into an open stream which must be uncontaminated.

This is no small problem, since the water in the plant holds soluble and insoluble oils, alkaline cleaner fluids, mineral acids, corrosive salts, and other contaminants. The quantities of these compounds vary from hour to hour so the waste is at times predominantly acidic, at other times predominantly alkaline.

International's Fort Wayne Works is solving the problem and solving it economically . . . with a Colloidair Separator.

Air is dissolved in the raw wastes as they pass through a retention tank. A pump feeds proper proportions of aluminum sulfate to obtain an optimum pH; with activated silica, the sulphate forms a floc to collect the oil.

The waste is then released to atmospheric pressure in the flotation vessel. Tiny air bubbles, released from solution, lift the floc with its oil particles to the surface, where it is skimmed off.

Clarified liquid discharges from the tank bottom. The skimmed oil wastes are sent to open pits to dry.

The effluent holds less than 10 ppm oil, low enough for dumping into the open stream. This figure can be reduced to zero by further treatment, should International want water for reprocessing.

If you'd like to find out more about the Permutit Colloidair system and how it can handle your waste problems, Circle "B" on the coupon.

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DICS

is a Pfaudler Permutit program providing

the know-how

the equipment

and the experience

for solving problems involving fluids

FLUIDICS covers such varied phases of fluid handling and control as:

- **corrosioneering**
- **water treatment**
- **waste treatment**
- **reactions**
- **polymerization**
- **ion exchange**
- **fluid analysis, metering and control**
- **agitation**
- **evaporation**
- **distillation**
- **drying**
- **blending**
- **metering**
- **valving**
- **flow rate control**
- **piping**
- **storing**
- **centrifuging**
- **filling**
- **heat transfer, etc.**

Whenever you have a fluid-handling problem, look to this Pfaudler Permutit FLUIDICS program for the best solution.

FLUIDICS AT WORK

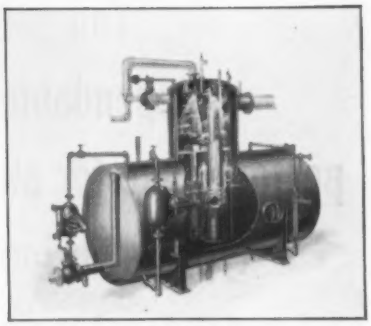
Large Glasteel storage tanks cost less than stainless steel

Hard-to-store chemicals, in quantities of 10,000 gallons and over, cost less when you store them in Glasteel Chemstor tanks.

Save on Initial Costs. When you get in the 30,000-gallon range, for instance, the initial cost of Chemstor tanks is actually about half that of comparable stainless steel tanks.

Save on storage handling costs. You can stop worrying about corrosion and contamination losses, because the stored product touches only chemically inert glass. Glass is easy to clean and keep clean, too. Its naturally smooth surface discourages clinging, scale, and product build-up.

For details, circle "C" on the coupon.



FLUIDICS AT WORK

New deaerator scrubs water to 0.005 ml/l of oxygen

If you're looking for a way to free water almost completely of gases, you'll look far before you find a more efficient unit than this Permutit Type B deaerator.

You can push as much as 150,000 lbs/hr through one of these and reduce the oxygen content to as little as 0.005 ml/l.

Our Type A deaerators handle up to 3,000,000 lbs/hr, if you're interested in really large capacity.

Both types are available in either horizontal or vertical designs.

For details, circle "D" on the coupon.

PFAUDLER PERMUTIT INC. ▪ **Permutit Div., Dept. PR-69, 50 W. 44th St., N.Y. 36, N. Y.**

Circle Items Wanted: A B C D

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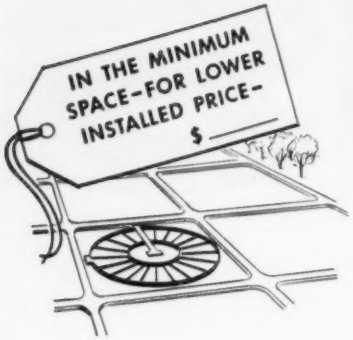
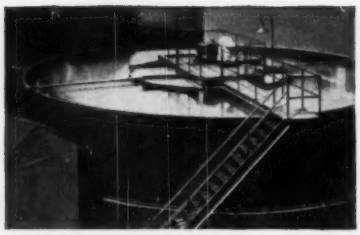
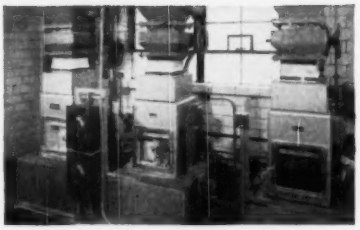
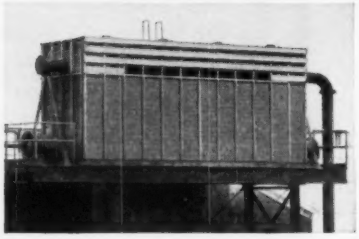
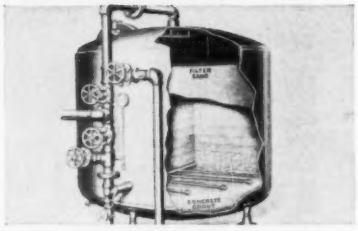


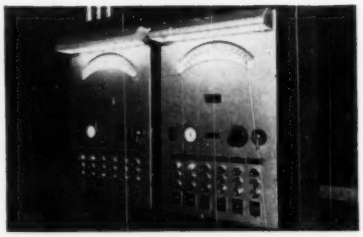
You get dependable performance for all types of brine and water treatment with INFILCO equipment











ACCELATOR®
plants for clarification, softening and stabilization
Effective mixing of chemicals and raw water with recirculating slurry and downflow separation effect better treatment in minimum area — and at low cost. For water, brine or waste treatment.
BULLETIN 1825

CHEMICAL FEEDERS
Accurately controlled feed rates and maximum economy
Compact designs for automatic or manual control, for all types of chemicals. Type E Feeders dispense dry chemicals volumetrically, from bulk storage to dry or wet applications. BULLETIN 215

NEUSOL® FEEDERS
Wide feed range, corrosion resistant construction adapt this versatile and dependable displacement feeder to most chemical solution requirements.
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AERATORS and DEGASIFIERS
For all types of gas-liquid transfer applications. Efficient oxidation, carbon dioxide and hydrogen sulfide removal.
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Request information on recarbonators, deaerating heaters and vacuum degasifiers.

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Standard or special construction for the most exacting process requirements
Vertical or horizontal, sand or anthracite types with manual or automatic controls for water or brine filtration. BULLETIN 1520
The STELLAR® diatomite filter, with its exclusive "gas-bump" cleaning is standard for amine solutions in most of the largest gas companies. BULLETIN 1560

MODERN INSTRUMENTATION
Maintains efficiency, reduces operating cost of treatment
Design and assembly of pneumatic, electric or hydraulic control components for manual or automatic, constant or variable rate plants. Operating consoles and control panels specifically engineered for complete treating plants. BULLETIN 1100

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INFILCO CAN help you solve any water and brine treatment problem in oil production and refining

From experience, extending over 60 years, INFILCO can give you the best results with lowest *first* cost and *operating* costs.

No other line of equipment is so complete—none so advanced in method and design. Above are a few examples.

It will pay you to investigate. Inquiries are invited on all matters relating to water or brine treatment. Write today for new condensed catalog, Bulletin 80, for a more complete description of INFILCO products.

THE ONLY COMPANY impartially offering equipment for ALL types of water and waste processing—coagulation, precipitation, sedimentation, flotation, filtration, ion exchange and biological treatment.

NOW! General Chemical offers 2 New Brochures on SULFAN® stabilized sulfuric anhydride

To help you save on sulfonations, sulfations

Sulfan offers more than 99% available SO_3 in easy-to-handle liquid form

- nine times as much usable SO_3 as 100% sulfuric acid
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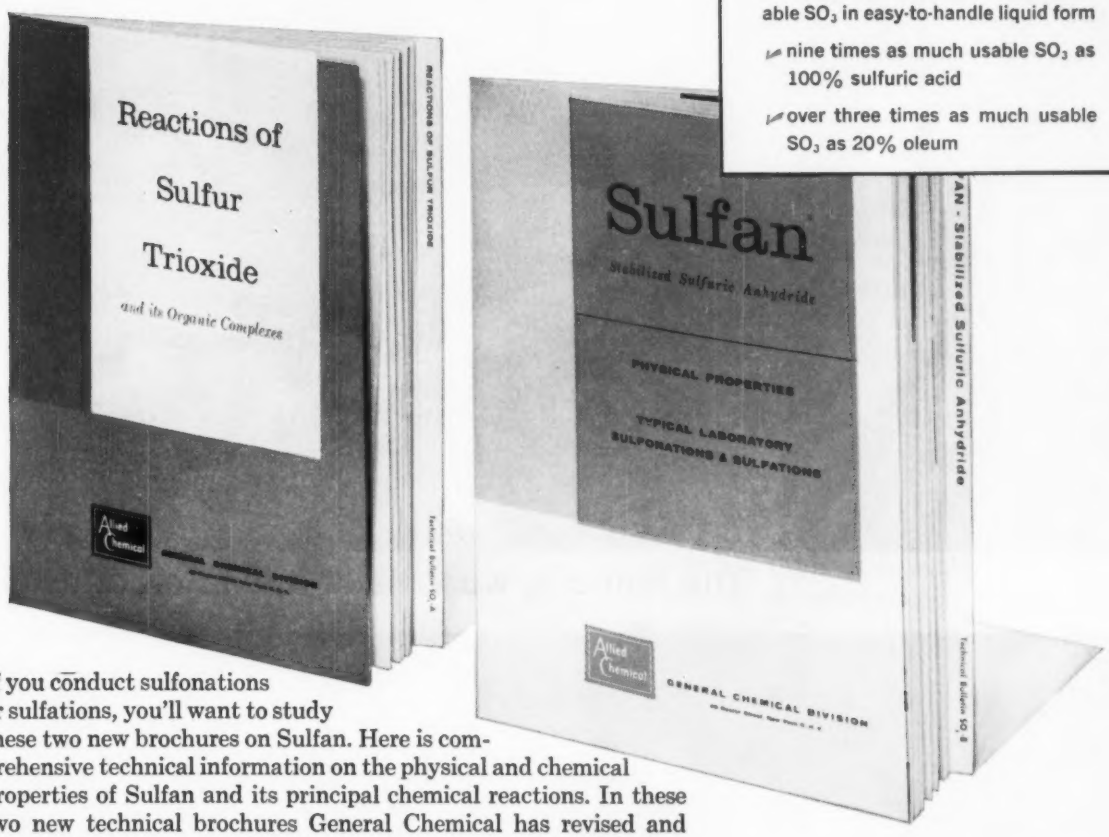

If you conduct sulfonations or sulfations, you'll want to study these two new brochures on Sulfan. Here is comprehensive technical information on the physical and chemical properties of Sulfan and its principal chemical reactions. In these two new technical brochures General Chemical has revised and brought up to date the literature previously available on Sulfan. New information has been incorporated. Be sure to send for your copy of:

"Reactions of Sulfur Trioxide" (20 pages)

Covers reactions of SO_3 and its organic complexes (such as pyridine, dioxane, trimethylamine) with organic compounds to form sulfonates or sulfates. Although we have not attempted to give complete coverage of any particular reaction, you may be able to draw analogies respecting reaction rates, temperatures, solvents and other conditions which can lead to successful and economical methods of employing Sulfan in new applications.

"Sulfan" (28 pages)

Compiled for those interested in sulfuric anhydride for fundamental research, product development or industrial production. Includes a description of the physical and chemical properties of Sulfan, correct procedures on handling and disposal, safety precautions, typical laboratory sulfonations, production of anhydrous HCl, fortification of spent acid with Sulfan and other helpful technical information.

Mail coupon now for your free copies!

Basic to America's Progress

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ALLIED CHEMICAL CORPORATION
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Please send your free Sulfan brochures checked below.

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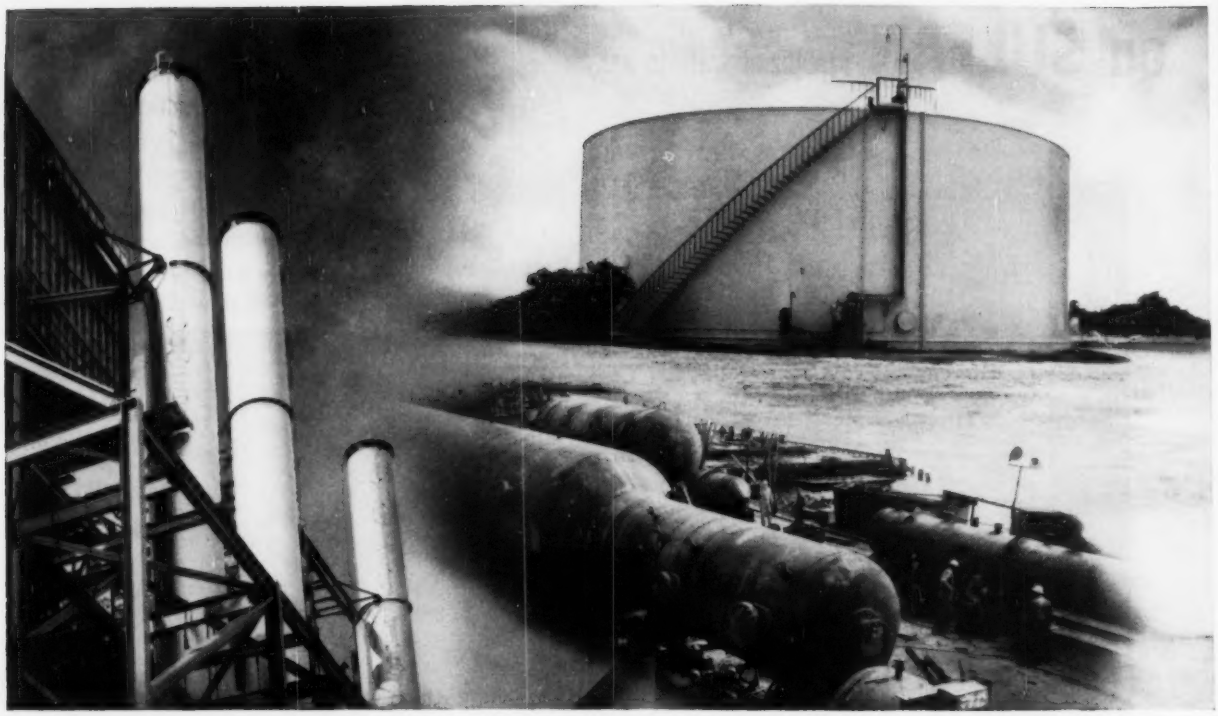
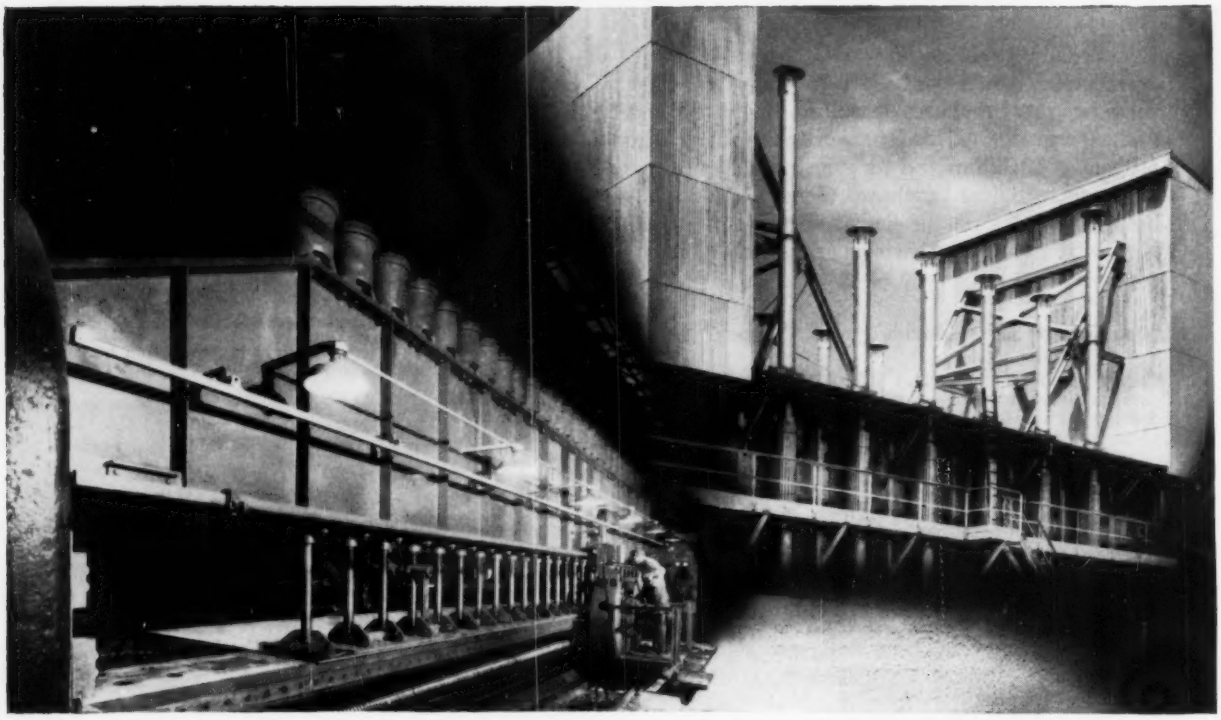
Top-Quality



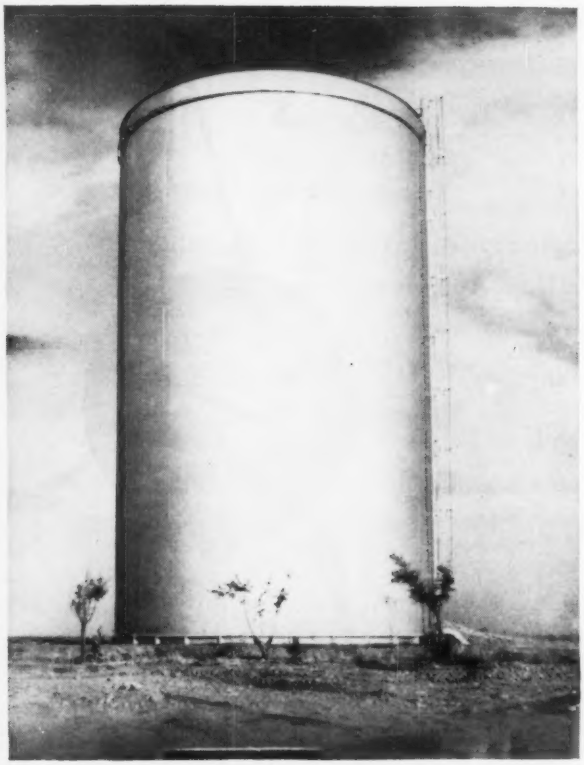
You name it, we'll make it; and erect it too!

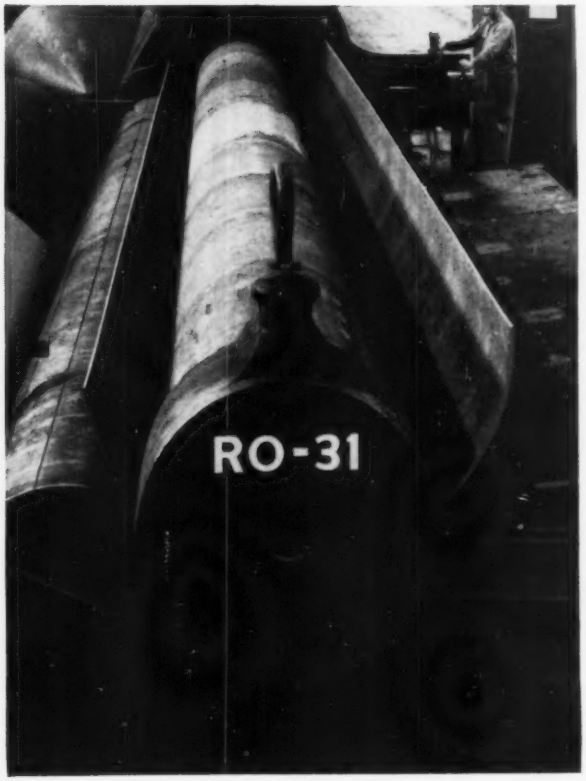


Complete, modern fabricating facilities.

Plate Fabrication

by American Bridge





OUR completely modernized fabricating plant at Orange, Texas, is now equipped to handle any type and size of custom plate work—from stacks, pipe, bins and tanks to heavy-wall pressure vessels.

And, because of its strategic location on water, rail, and truck routes, you can count on fast delivery and low shipping costs.

We are equipped to handle your plate work from start to finish—from fabrication to erection—efficiently and economically. We are also prepared to quote on any individual part of your plate requirements.

Modern facilities to handle important jobs. Our large, two-aisle building has seven cranes capable of lifting, in combined use, over 100 tons; large car bottom-heating and stress-relieving furnaces; heavy plate bending rolls; a variety of presses and press brakes; the latest in welding and X-raying equipment, plate shears, edge planers, boring mills and drills.

For top-quality plate work, get in touch with the nearest office. Or, write for our new booklet which completely describes the facilities and services available from our Orange plant.

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you can eliminate shaky temperature readings

Even when the equipment is vibrating so that its outlines are blurred, you can take a quick, accurate temperature reading from an RMC thermometer.

Resistance to vibration is built into every RMC thermometer. Our engineers have done it so thoroughly that if there is any pointer oscillation it is not apparent. You always *know* what the temperature is within ½ to 1% accuracy to which the thermometers are made.

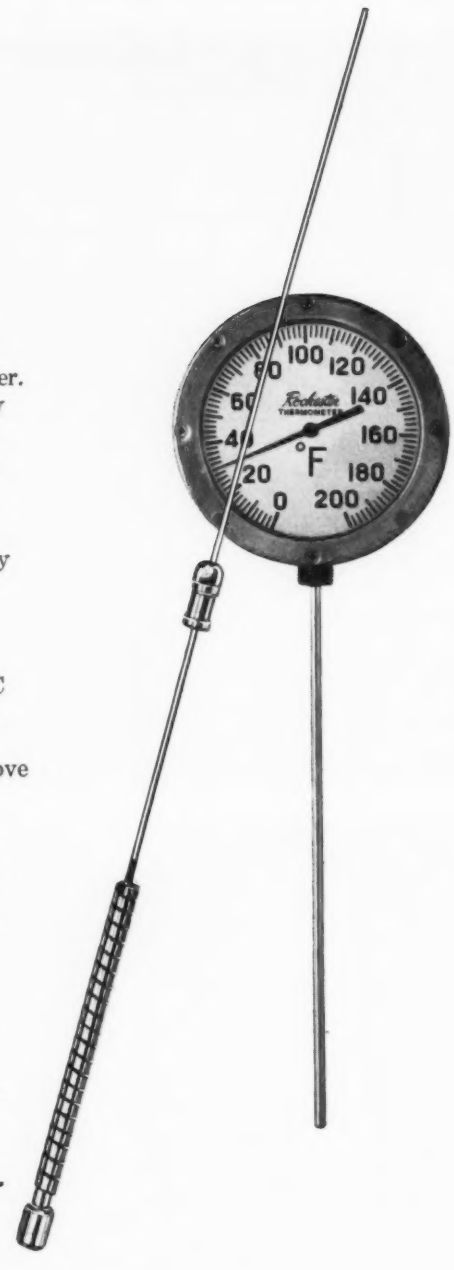
The engineering department's dislike for vibration goes beyond the desire to eliminate the annoyance and inaccuracy of a shaky needle. Vibration, unless it is controlled, can cause the bimetallic heat-sensing element to unwind partially and throw the instrument out of calibration.

None of these things can happen to you when you use RMC thermometers, because they are doubly dampened . . . first, by treatment with silicone dampening fluids . . . secondly, by the use of a special dampening bearing, just above the bimetallic element to dampen movement of the shaft as well as to maintain its alignment within the tube.

This is just one of the exclusive features we put into RMC thermometers to make sure that they will serve you accurately and long. When you look at a thermometer you want to *know* it's right . . . and we want you to know that if it's an RMC you can be sure.

Accuracy is a lot of little things—as well as a painstaking attention to detail, but it's our business.

If you have a temperature, liquid level, or pressure reading problem, why not turn it over to our engineers. Just wire, write or phone.



Ralph Foster

RMC

ROCHESTER MANUFACTURING CO., INC.
38 ROCKWOOD STREET • ROCHESTER 10, N. Y.

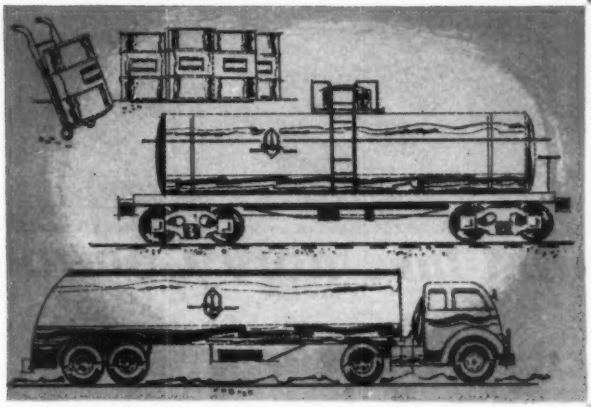
LIQUID LEVEL, TEMPERATURE AND PRESSURE INSTRUMENTS

Representatives in all Principal Cities

Gas Processors get all three from Jefferson!

THE RIGHT CHEMICALS . . .

for efficient Natural Gas Sweetening, Refinery Stream Sweetening, Sulfur Recovery, Solvent Extraction, Carbon Dioxide Absorption, Gas Dehydration, and Hydrate Prevention.

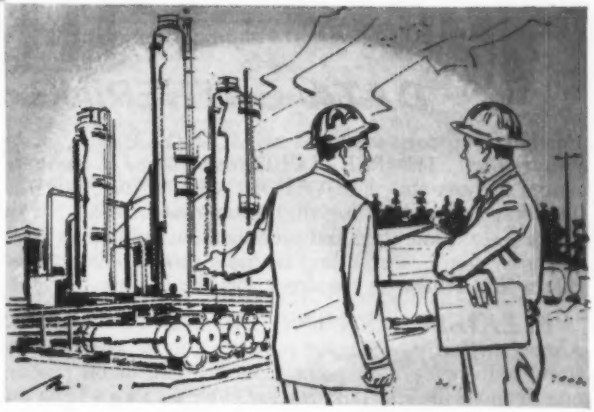


ON-SCHEDULE DELIVERIES . . .

when and where and in any quantities you require . . . 55-gal. drums, 1-4,000-gal. tank wagons, 4-10,000-gal. tank cars . . . single product or combination shipments.

HELPFUL TECHNICAL SERVICES . . .

like those relating to proper storage and handling, or complete analyses of your gas-scrubbing agents, or just any way the Jefferson people can help you lick a problem. Your request to 1121 Walker Avenue, Houston 2, Texas, will bring helpful answers on the double.



Ethylene Oxide, Glycols, Dichloride • Ethanolamines • Morpholine • Piperazine
Polyethylene Glycols • Nonyl Phenol • SURFONIC® Surface-Active Agents
Ethylene Carbonate and Propylene Carbonate • Caustic Potash • Caustic Soda
Soda Ash • Sodium Bicarbonate

Essential Chemicals From Hydrocarbon Sources

JEFFERSON CHEMICAL COMPANY, INC.

HOUSTON • NEW YORK • CHICAGO • CLEVELAND
CHARLOTTE • LOS ANGELES

147

For more data on advertised products, use Readers' Service Cards, last page.

for TANK FARM Inventory Control

"Varec" Pulse Code

DATA GATHERING AND REDUCTION SYSTEM

For handling such variables as LIQUID LEVEL *(in feet, inches and eighths; metric in millimeters or feet and hundredths);* TEMPERATURE *(one degree increments to three digits);* PRESSURE *(three digits in one or ten pound increments);* FLOW VOLUME *(to five or six digits in one or ten barrel increments or other volume units).* The system will also log the status and provides for the control of operating equipment such as valves, pump motors, etc. Time data and identification points can be recorded as needed to suit the operation. Flexibility is one of the system's outstanding features since it allows the use of standard proven systems for custom applications that would otherwise require special-built, untested units.

FLEXIBLE ARRANGEMENT

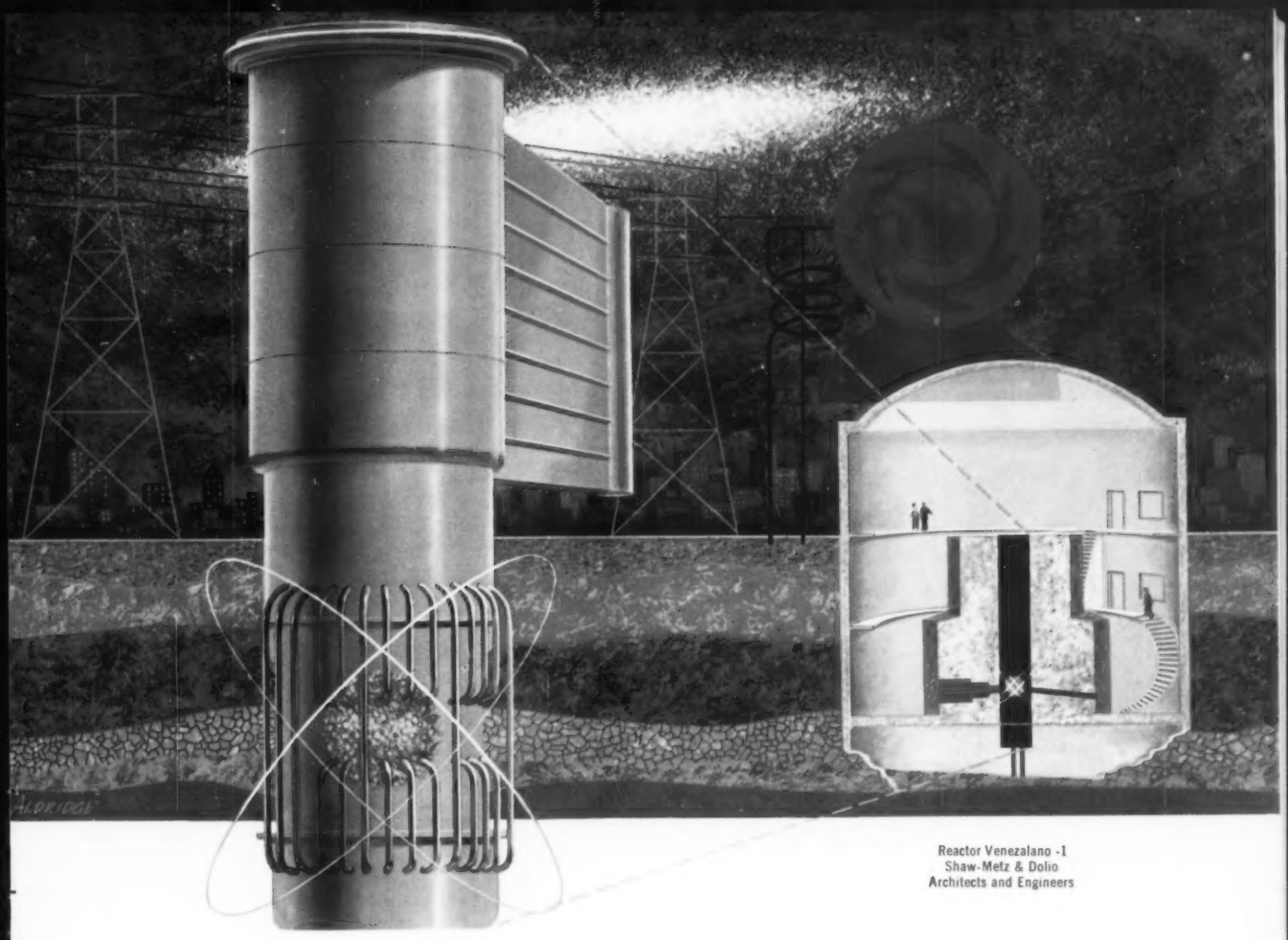
Almost any type of logging program can be arranged by using standard sub-assemblies: Logging on prearranged form, with or without point identification, or on random order basis with point identification •••••• Entry of one or more lines of data for log cycle •••••• Time entry at start of each line entry. All numbers, fractions and letters available for logging; carriage shift; black-red ribbon shift provisions.

FLEXIBLE OPERATION

Manual operation without Data Logging by means of a telephone dial which obtains a visual indication of any point included in the system ••••• Manual control of Scanning-Logging Cycle can be started at any time by the operator at any desired point ••••• Automatic Control of Scanning-Logging Cycle can be initiated on a time programmed basis by time clock control.

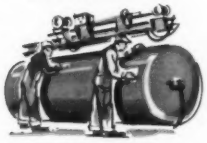
FOR A COMPLETE ENGINEERING APPROACH TO TELEMETERING SYSTEMS REQUEST PACKAGE 24

THE VAPOR RECOVERY SYSTEMS COMPANY • COMPTON, CALIFORNIA



Reactor Venezalano -1
Shaw-Metz & Dolio
Architects and Engineers

ENGINEERING



FABRICATION

FIELD ERECTION

Peaceful atoms at work

A bright spot in the future of the peaceful atom is the type of nuclear power plant now appearing in this country and others.

Solar Chicago fabricated the pool liner for such a power plant recently. The pool liner—that's the vertical cylinder shown above—is used to contain radioactive material.

Whether it's a fabricated structure to help harness the atom, a pressure vessel for chemical or petroleum processing, or a new type of vessel to improve a brewery process, you can look to Solar Chicago for a superior design and fabricating job.

The next time you need process equipment of any type, give us a call. We'll meet the most rigid requirements for quality—the toughest delivery schedule.

Write today for our brochure

USI Solar Chicago DIV. U.S. INDUSTRIES, INC.

6400 W. 66th St., CHICAGO 38, ILL.

Telephone POrtsmouth 7-8900

FORMERLY CHICAGO STEEL TANK CO.

OFFICES IN:

Jacksonville Beach, Florida
R. W. Fowler & Assoc. Inc.
P. O. Box 101
Cherry 6-2477

Tulsa, Oklahoma
Mr. R. J. Dunham
716 Wright Bldg.
Diamond 3-8165

New York
Solar Chicago
274 Madison Avenue
Murray Hill 7-9298

Louisville, Kentucky
Solar Chicago
2416 Frankfort Ave.
Twinbrook 5-5389

Los Angeles, California
R. D. Morrison
1324 Wilshire Blvd.
Hubbard 3-4369

REPEAT BUSINESS...

Commendation of Performance

Creole Petroleum Corporation of Venezuela, one of the world's largest producers of crude oil, has pursued a dedicated course of conservation and maximum utilization of Venezuela's natural resources. In so doing, complex engineering problems in gas injection have been created.

An organization of the magnitude of Creole can readily command the very best engineering and construction talent available . . . and Brown & Root felt signally honored when in 1952 they were awarded a contract to design and construct a 60,000 horsepower gas injection station, to be located 7 miles from shore in Lake Maracaibo. The job was loaded with "firsts" and superlatives. For example, it was the first time centrifugal compressors were ever used to compress gas to 2000 p.s.i. This tremendous amount of horsepower was to be housed on a platform in 62 feet of water, with all the related problems of vibration, corrosion, noise and self-containment.

Evidence that the client was pleased with this $20 million project came when Brown & Root was awarded a contract to design and construct Conservation Plant Tía Juana Two of 84,000 horsepower, and then again Brown & Root was successful in obtaining the design and construction contracts for Tía Juana Plant Three of 98,000 horsepower. Conservation Plant Bachaquero One, Creole's fourth repressuring station, is currently on Brown & Root's drawing boards.

BROWN & ROOT, INC. *Engineers · Constructors*

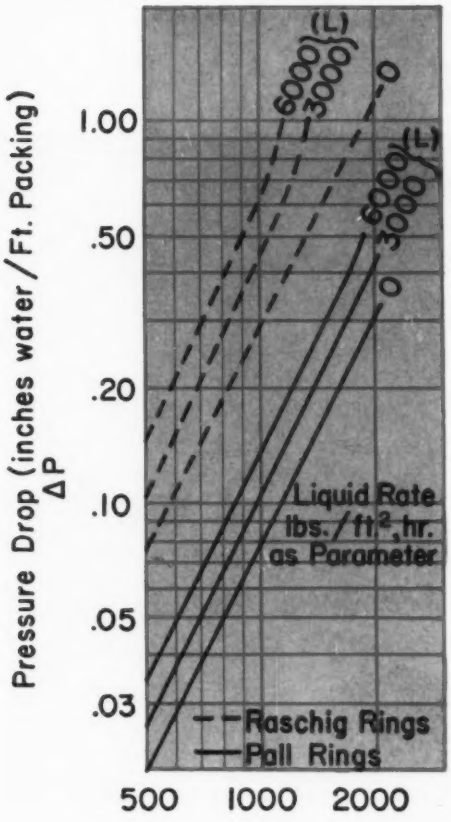
POST OFFICE BOX 3, HOUSTON 1, TEXAS

Brown & Root, S. A., Panama City, Panama
No. One Wall Street, New York 5, New York
P. O. Box 4140, South Station, Edmonton, Alberta
Pennsylvania Building, Washington, D. C.
Brown & Root Construcciones, S. A., Caracas, Venezuela
Brown & Root de Mexico, S. A. de C. V., Mexico City, Mexico
Brown & Root, LTDA., Santos, Sao Paulo, Brazil
CABLE ADDRESS – BROWNBILT

Cut Tower Volume 20% to 40%

with

METAL PALL RINGS



PRESSURE DROP vs. GAS RATE

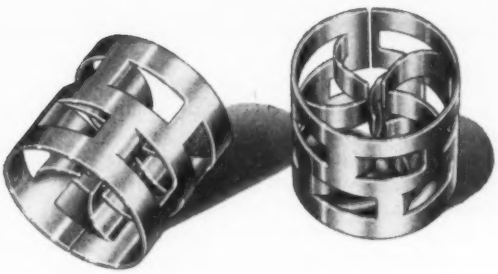
Where conditions suggest the use of metal packing rings in absorption operations, here's an important point to remember:

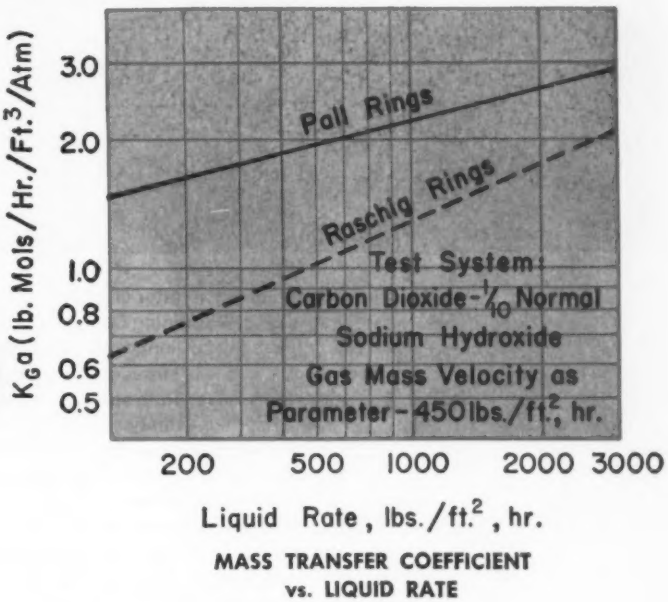
Tower volume can be reduced substantially by using metal Pall Rings in place of metal Raschig Rings.

Take a careful look at the graphs. They show capacity data and pressure drop data taken from tests run not in an eight or twelve inch tower but in our new 30" diameter experimental tower. The tests were made using 1½" rings, packed to a depth of 8 feet.

This improvement in performance results purely from the characteristics of the Pall Ring. The Pall Ring differs from the conventional Raschig Ring in that sections of the ring wall are stamped and bent inward permitting better circulation of liquid and gas. Thus, more surface area is wetted resulting in greater active contact area between phases.

Metallic Pall Rings are made at present in 1", 1½" and 2" sizes in carbon steel, stainless steel, aluminum and copper.





MASS TRANSFER COEFFICIENT vs. LIQUID RATE

For full information —

on Pall Rings and on other tower packings, write for a copy of Bulletin TP-54.

U. S. STONEWARE

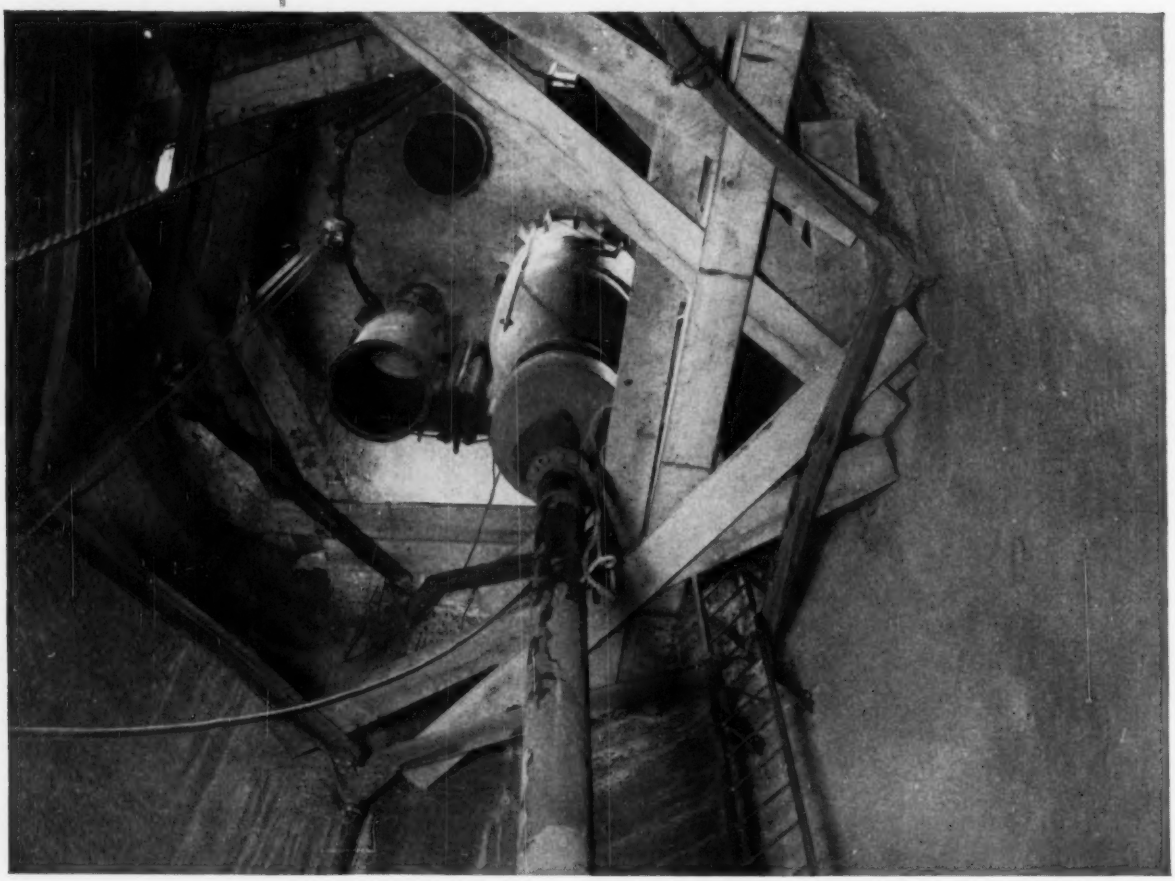
AKRON 9, OHIO

101-F

For more data on advertised products, use Readers' Service Cards, last page.

Five years later:

No repairs needed on regenerator's refractory concrete lining made with **Atlas Lumnite Cement**



When this regenerator chamber was opened at the Canton (Ohio) refinery of the Ashland Oil & Refining Company after five years of service, the refractory concrete lining was in excellent condition. No replacement was needed. The smooth, jointless surface of the concrete, made with Lumnite calcium-aluminate cement, was free from spalling. It resisted abrasion by catalyst and the penetration of gases. In other refinery equipment (heaters, vapor separators, transfer lines, cyclones, stacks, breechings, etc.), refractory concretes made with Lumnite cement can be designed to meet every operating condition. For extra convenience and economy, castables containing Lumnite cement are available from leading manufacturers of refractories. These are packaged mixtures, requiring just water and mixing. For more information, write Universal Atlas, 100 Park Avenue, New York 17, N. Y.

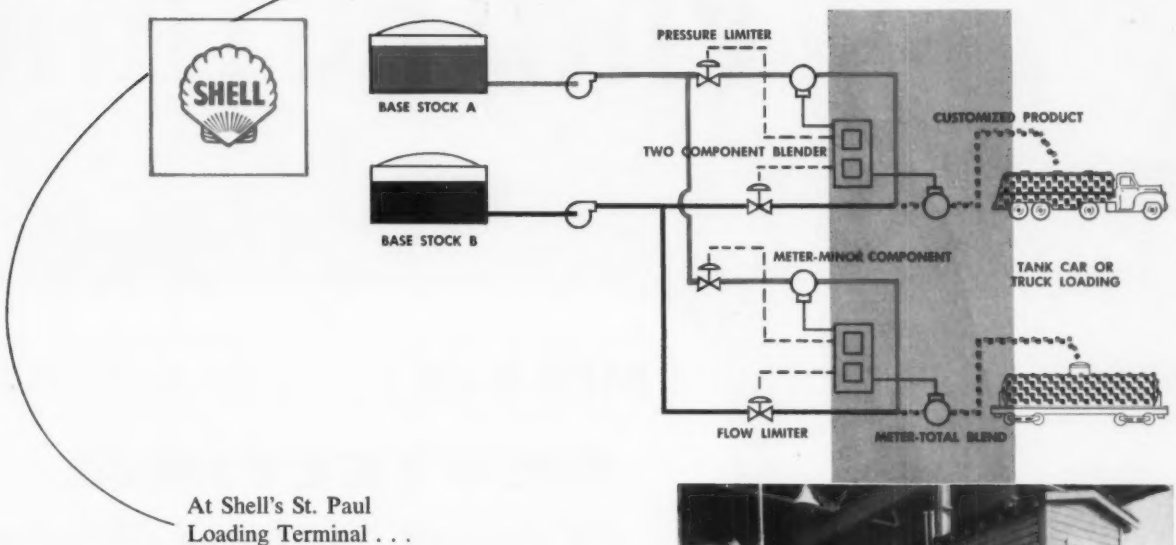
"USS" and "Lumnite" are registered trademarks L-182

Universal Atlas Cement
Division of
United States Steel

OFFICES: Albany · Birmingham · Boston · Chicago · Dayton · Kansas City · Milwaukee · Minneapolis · New York · Philadelphia · Pittsburgh · St. Louis · Waco

POSITIVE CONTROL OF MATERIALS IN MOTION

BIF METERS FEEDERS CONTROLS



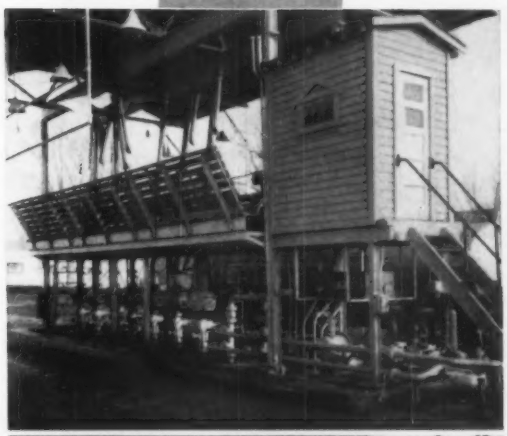
At Shell's St. Paul Loading Terminal . . .

FLICK-OF-FINGER SOLVENT FORMULA CHANGES!

With BIF *Proportioneers* Blenders,

a flick of a dial and any two base stocks can be specification-blended on the spot . . . without the need for intermediate tankage! Costly time losses at the loading rack are completely eliminated. Any blend of two base stocks can be duplicated with complete uniformity . . . any number of times . . . at formulation ranges from 5% to 95% for either component to suit exact customer requirements.

At this Shell installation, like those at Wagner's Point, Md. and Fall River, Mass., Proportioneers in-line TC blending systems custom-blend solvents *directly* to truck or tank car . . . providing quick-change formula flexibility that speeds terminal activity. Proportioneers systems are totally integrated and enclosed . . . designed for completely automatic, safe, accurate handling of petroleum products. Percentage ratios are easily and quickly set . . . operation is "fail-safe" under all conditions. Written *guaranteed accuracy!*



Write for complete data . . . to
B-I-F Industries, Inc.
Dept. P. 412 Harris Avenue,
Providence 1, Rhode Island

B-I-F

B-I-F INDUSTRIES

BUILDERS-PROVIDENCE · PROPORTIONEERS · OMEGA

For more data on advertised products, use Readers' Service Cards, last page.

PROTECTION

MEX-R-CO

PROTECTION

For Extreme Erosion and Abrasion

Where a high-strength, high-purity, volume-stable refractory material is required, MEX-R-CO Refractory Castable products will meet the most severe service conditions. All MEX-R-CO Castables are scientifically developed and job-matched for protection-in-depth application.

- **KEEP UNITS ON-THE-LINE-LONGER**
- **INCREASE PRODUCTION**
- **REVERSE RISING REFRACTORY COSTS**

Use MEX-R-CO Castables for these Applications

Blast furnace linings . . . Auxiliaries (lines, goosenecks, etc.) . . . Blast furnace packing . . . Dust collectors . . . Flues . . . Soaking pit covers and walls . . . Coke ovens . . . Refinery units (catalytic crackers, reactors, reformers, fluid cokers, and lines) . . . Carbon black furnaces (reactors, etc.) . . . Desulphurizing units . . . Special chemical reactors Jet strips and launching pads.

COMPLETE SPECIFICATIONS for installing and maintaining MEX-R-CO Refractory Castable products will gladly be sent on request. Booklet covers Selection, Water Content, Mixing, Placement, Gunning, Anchoring, Finishing, Curing, Drying and Firing.

MEXICO
REFRACTORIES COMPANY
MEXICO, MISSOURI

IN DEPTH!

FOR TEMPERATURES FROM 700°F TO 3600°F

MEX-R-CO

PROTECTION

Under These Service Conditions

1. **Velocities of 130-feet, and above, per second, in dilute phase lines**
2. **Velocities above 8-feet per second in dense phase lines, or in dust collectors**
3. **Turbulent flows — or blasts**
4. **Coarse grain catalyst, equilibrium coke, or sinter dust**
5. **Abrupt change in direction or any combination of the above conditions**
6. **High production cyclones and similar areas**

MEX-R-CO service-proven, extreme erosion- and abrasion-resistant castables are high in purity, extra strong . . . and easy-to-apply. Service performance records indicate it is important to select the RIGHT Castable in the beginning and avoid the high cost of early repair and replacement. It does not cost more to employ the best. In-service time should be the deciding factor. For "Protection-in-Depth" use and specify MEX-R-CO Refractory Castables.

LO-ERODE

PURO-TAB

ACITAB

B F CASTABLE

PUROCAST

F-334-S

PAK (Blast Furnace Packing)

STANDARD HEAVYWEIGHT AND LIGHTWEIGHT INSULATING CASTABLES

This coupon will bring complete technical data on MEX-R-CO Refractory Castable Products. No obligation.

MEXICO REFRACTORIES COMPANY
MEXICO, MISSOURI

Send complete information on Refractory Castable products for installation in (Type of Unit)

Have your engineer contact us.

NAME

COMPANY

ADDRESS

MEXICO REFRACTORIES COMPANY
Division of
KAISER ALUMINUM & CHEMICAL SALES, INC.
Mexico, Missouri, U.S.A.

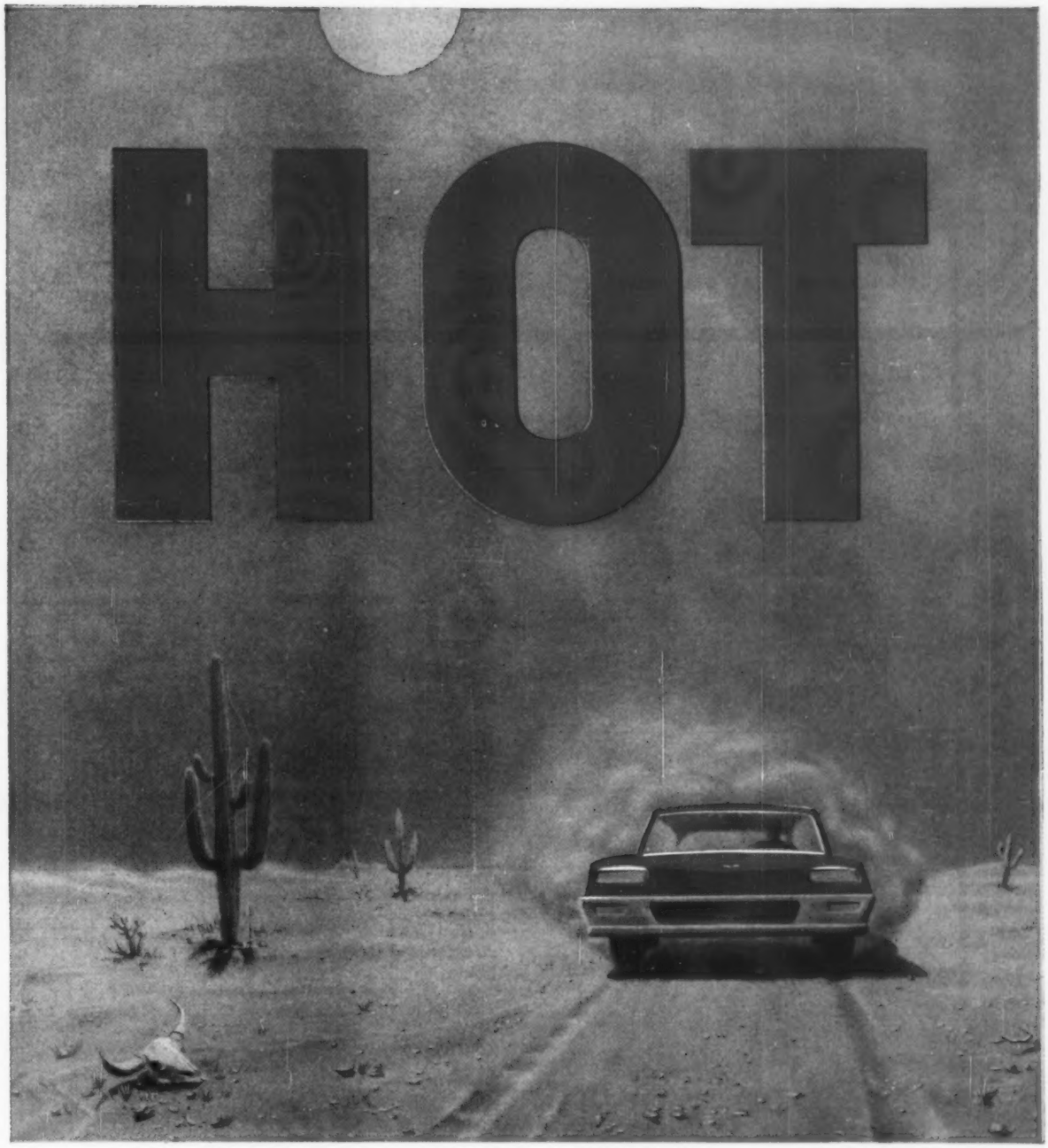
Machines also available on rental basis

"NO SHUTDOWN WHILE CUTTING INTO THE LINE with a WmSon-Hillco Tapping Machine. When the tap is completed, Williamson Stopples plug the line temporarily while the flow continues through a by-pass. You can make repairs, replace piping, connect process units and booster stations, install fittings, extend or abandon piping. It's all done without shutdown and **WITH COMPLETE SAFETY!"**

Offering years of research and experience in hot tap operations

T.D. Williamson, Inc.
P. O. BOX 40 TULSA 2, OKLAHOMA

REPRESENTATIVES AROUND THE WORLD



OR COLD... PARATONE-BLENDED OILS STAND UP!

When the heat's on, inside and out . . . metal-scorching temperature in the engine—sweltering radiation from the hot summer sun . . . ordinary oils become dangerously thin. But oils blended with Enjay Paratone® viscosity index improver stand up to oil-thinning heat and retain their lubricating viscosity. Yet when winter sets in, Paratone-blended oils do not congeal to a heavy, sluggish oil. They provide instant lubrication to all parts for quick, cold weather starting. Enjay has developed the only complete line of high quality additives (Paramins®). To meet the most exacting oil specifications, insist on Enjay Paramins.

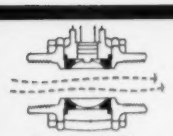
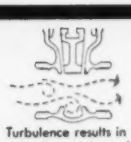
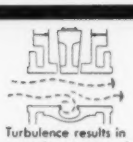
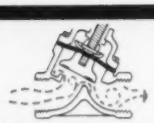
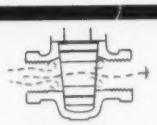
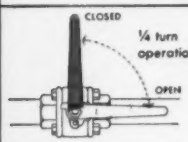
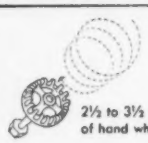
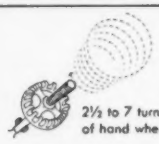
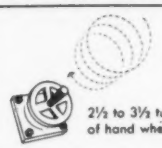
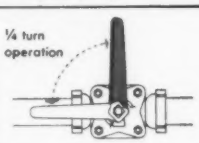
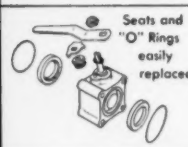
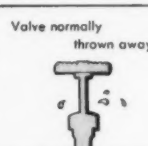
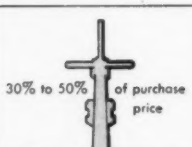
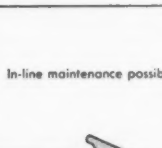
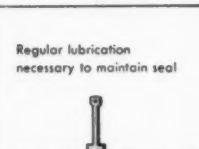
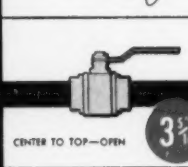
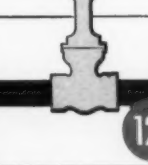
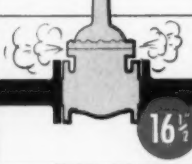
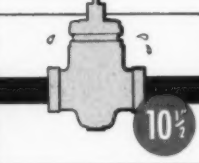
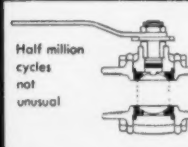
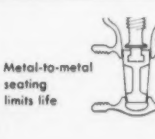
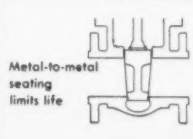
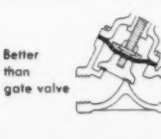
ENJAY

Pioneer in Petrochemicals

ENJAY COMPANY, INC., 15 West 51st St., New York 19, N. Y. • Akron • Boston • Charlotte • Chicago • Detroit • Los Angeles • New Orleans • Tulsa

For more data on advertised products, use Readers' Service Cards, last page.

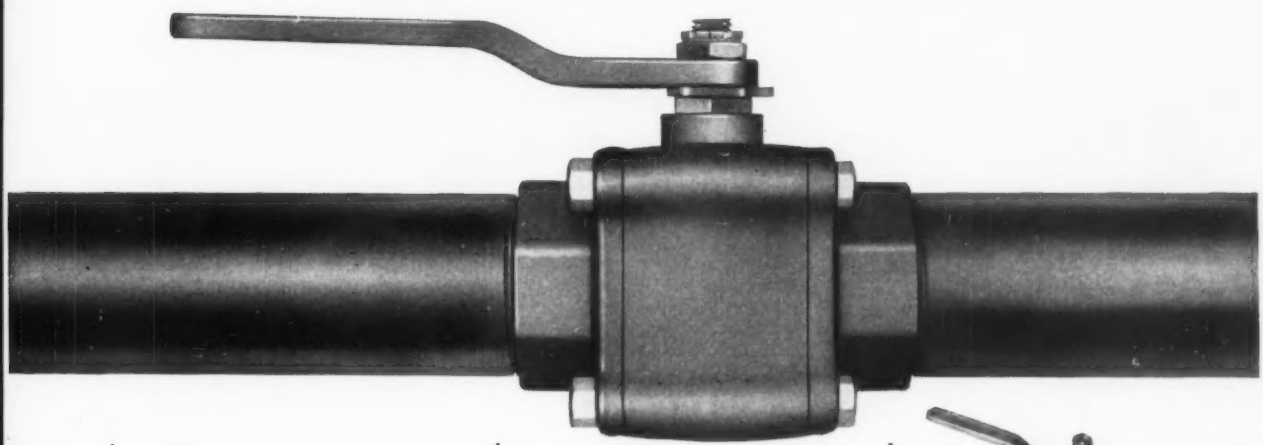
COMPARE . . .

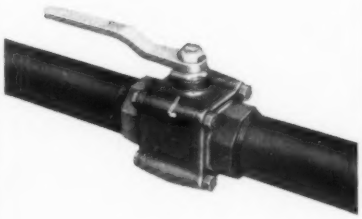
	ECON-O-MISER	GATE VALVE	FLANGED GATE VALVE	DIAPHRAGM VALVE	LUBRICATED PLUG VALVE
FLOW CHARACTERISTICS	 Smooth round flow	 Turbulence results in excessive pressure drop	 Turbulence results in excessive pressure drop	 Turbulence results in unusually high pressure drop	 Constricted flow . . . pressure drop
METHOD OF CLOSURE		 2½ to 3½ turns of hand wheel	 2½ to 7 turns of hand wheel	 2½ to 3½ turns of hand wheel	 ¼ turn operation
MAINTENANCE CHARACTERISTICS	 Seats and "O" Rings easily replaced	 Valve normally thrown away	 30% to 50% of purchase price	 In-line maintenance possible	 Regular lubrication necessary to maintain seal
SIZE 3"-TO SCALE		 12 5/8	 16 1/2	7 1/4	 10 1/2
LIFE EXPECTANCY	 Half million cycles not unusual	 Metal-to-metal seating limits life	 Metal-to-metal seating limits life	 Better than gate valve	Very good if lubricated regularly

THE ECON-O-MISER BALL VALVE IS THE IDEAL REPLACEMENT FOR MOST ON-OFF VALVES NOW IN USE IN THE PROCESS INDUSTRIES!

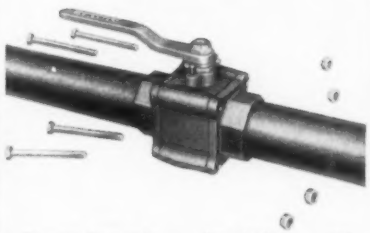
MORE EFFICIENT . . . LESS COSTLY

THE ECON-O-MISER BALL VALVE

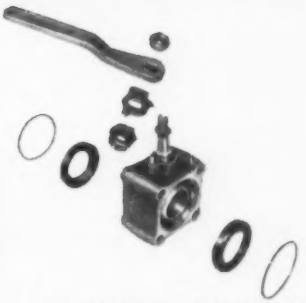




Compact, efficient ECON-O-MISER Ball Valves are today's smoothest operating on-off valves. A quarter turn of the handle allows full operation and you can tell at a glance whether the valve is open or closed. More . . . ECON-O-MISER Ball Valves act as both valve and union . . . eliminate costly inventory and labor. Minimum turbulence and greater economy make this valve ideal for hundreds of applications.



Remove four nuts . . . four bolts . . . and the entire center section lifts out for servicing. Quick, convenient maintenance saves money **and** this unique design means pipe ends never have to be removed from the line. Seating surfaces and O-Rings are easily replaced . . . whole valve back in operation in minutes. Reduces inventory expenses and frees maintenance personnel from time consuming repairs.



The ECON-O-MISER Ball Valve is available in many combinations of seats, O-Rings and body materials. Almost any media can be handled by the ECON-O-MISER and sizes range from ¼" through 6". Made of bronze, aluminum, carbon steel, stainless steel or aluminum bronze. We'll be happy to furnish information or application data.

THE ONLY VALVE IN INDUSTRY THAT SERVES AS BOTH VALVE AND UNION!

Complete, technical information in new "Comparison" bulletin.

Request EB 101 on your letterhead or fill in coupon.

NAME _____ TITLE _____

COMPANY _____

ADDRESS _____

CITY _____ STATE _____

☐ Please forward bulletin EB 101. ☐ Please ask sales engineer to call for appointment. ☐ Send information on ECON-O-MISER FLANGE BALL VALVE.

WORCESTER VALVE CO., INC.

DEPT. B • 16 PARKER STREET • WORCESTER, MASS.

Centrifugally cast Thermalloy tube burst at 77,500 psi

Wrought tube burst at 70,100 psi

Burst tests prove 7,400 psi superiority of centrifugally cast Thermalloy® tubes

Hydrostatic pressure tests by Electro-Alloys established the rupture of a centrifugally cast Thermalloy tube section at 77,500 psi. Under the same conditions, wrought tubes of comparable section and analysis burst at 70,100 psi. These tests were conducted at room temperatures. Tensile tests show this strength margin increases substantially at the higher operating temperatures (1500° — 1800° F). The Thermalloy tube was tested *as cast*—without machining the inside or outside diameter. For further data, call your representative, or write Electro-Alloys Division, 1036 Taylor Street, Elyria, Ohio.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

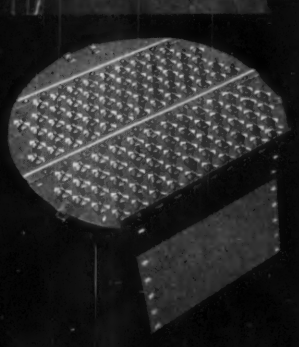
KOCH FLEXITRAYS

add higher capacities and efficiencies to Cities Service giant fractionating tower

This huge splitter, 13′ 6″ I. D. x 208′ 6″ overall length, erected in the Cities Service Refinery in Lake Charles, La., is believed to be the largest pressure vessel ever erected in one piece.

Koch Flexitrays make it tick. Flexitrays often save refineries and chemical plants 20% - 40% on total cost of complete tower installations.

On your next tower be sure to investigate Koch Flexitrays. The marked success of this low-priced tray has resulted in its use in more than 950 non-captive installations.



Contact your nearest Koch Representative, or write direct to...

KOCH

ENGINEERING COMPANY, INC.

321 West Douglas Avenue, Wichita 2, Kansas

Continuing progress through research

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BUTTE, MONTANA — G. M. Wallace & Co., P. O. Box 720
DENVER, COLORADO — G. M. Wallace & Co., 375 Denham Bldg.
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HOUSTON, TEXAS — Aloha Engineering Co., P. O. Box 12371
KANSAS CITY 13, MISSOURI — Samuels Brothers, P. O. Box 7063
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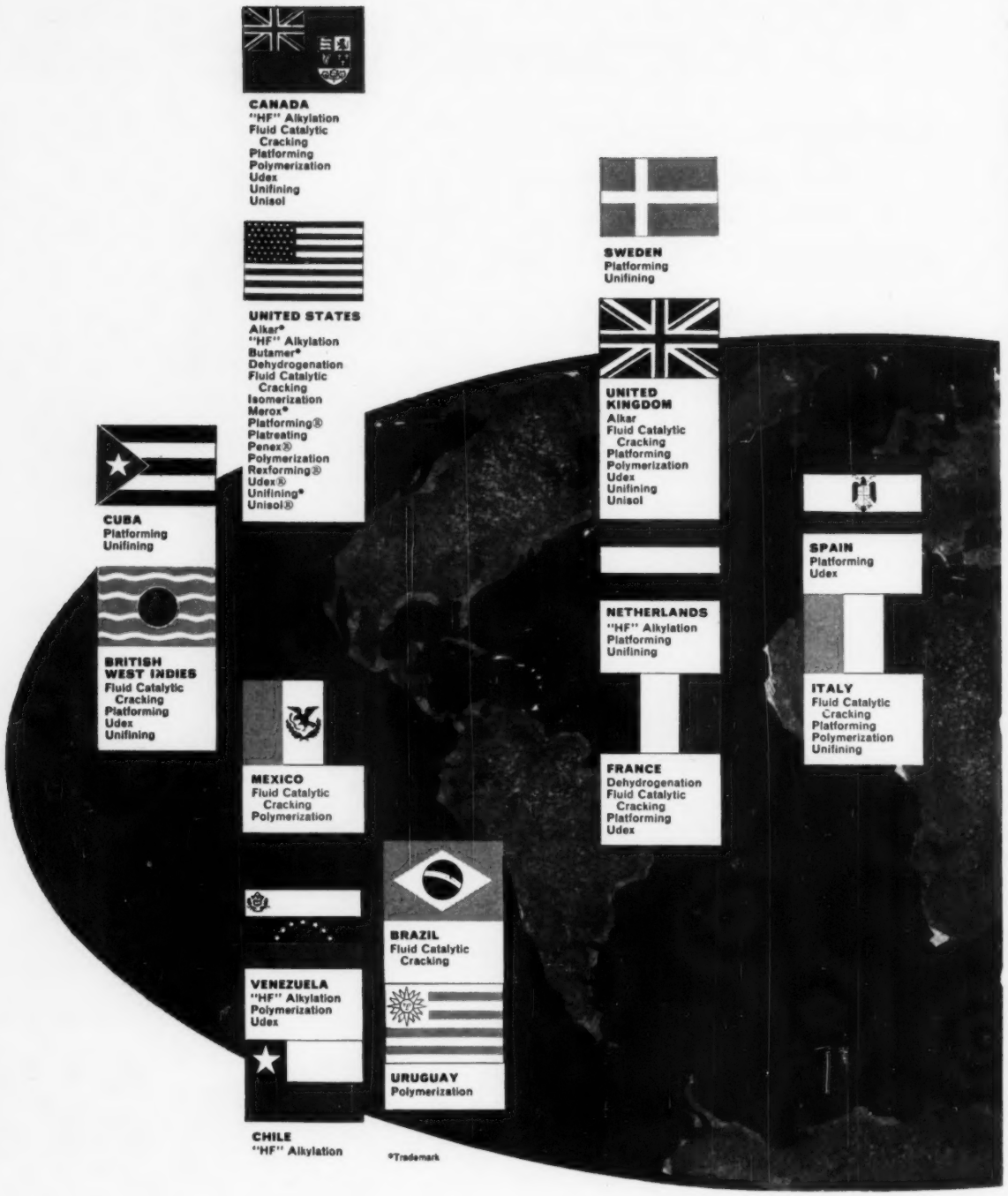
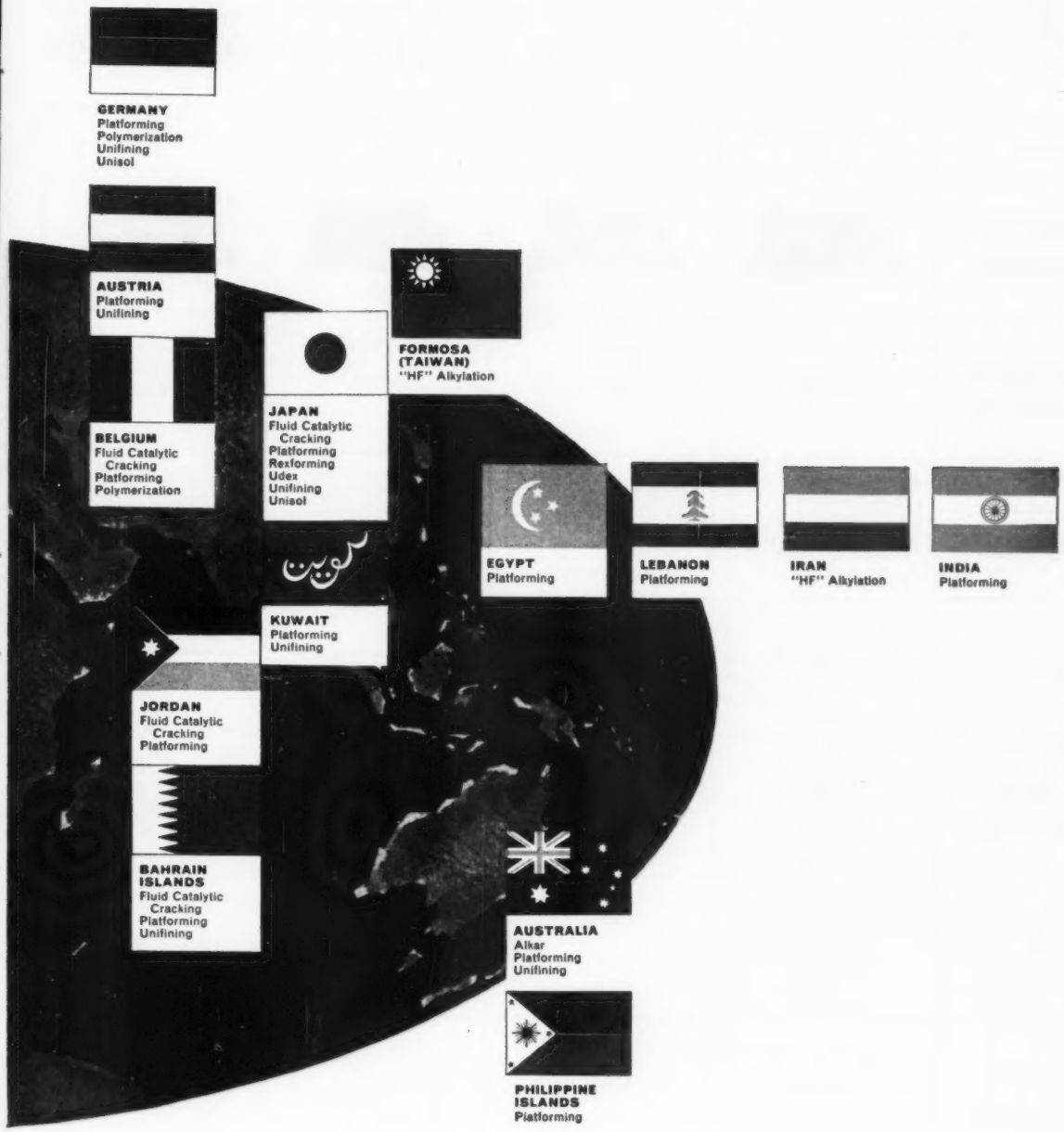
SOUTH CHARLESTON, WEST VIRGINIA — D. B. Fraser Co., 410 "D" St.
ST. LOUIS 17, MISSOURI — Samuels Brothers, 2010 Big Bend Blvd.
TULSA 16, OKLAHOMA — Myers-Ashley Co., P. O. Box 5436



CONTRIBUTIONS TO PETROLEUM PROGRESS . . .

Nearly one half-century ago, Universal Oil Products Company offered to the world a new and better way to refine crude oil. From that day to this the people of Universal have exerted unceasing effort to that end . . . to find new and better ways to process petroleum. The result of this endeavor is evident. Today, through the use of UOP processes and the help of UOP



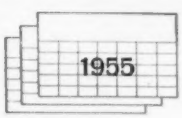
technology, petroleum refiners in twenty-nine countries throughout the Free World are making more and better products from petroleum . . . meeting increasing demands for higher-quality fuels and petrochemicals. In the future as in the past, UOP will continue to make important contributions to technological progress in petroleum.

UNIVERSAL OIL PRODUCTS COMPANY
30 Algonquin Road, Des Plaines, Illinois, U.S.A.
More Than 40 Years Of Leadership In Petroleum Refining Technology

For more data on advertised products, use Readers' Service Cards, last page.

THE UNVARNISHED FACTS

about engine compressors in the 375 to 950 hp range

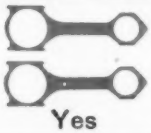
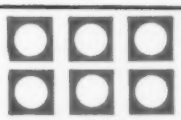
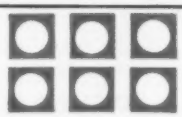
FEATURE	WORTHINGTON SLHC	MFR. A	MFR. B	MFR. C
DESIGNED FOR TURBOCHARGING	Yes	No	No	No
SELF-SUSTAINED TURBOCHARGING	YES	NO	NO	NO
FUEL CONSUMPTION	7,000 BTU/BHP HR	9,000 BTU's	8,600 BTU's	8,500 BTU's
CYCLE	4	2	2	4
CYLINDER ARRANGEMENT	Inline	Inline	Vee	Vee
RPM	450	600	450	400
YEAR ENGINE WAS DESIGNED	 1955	Before 1950	Before 1940	Before 1940
NUMBER OF DESIGNS TO COVER RANGE	1	2	2	2
LARGEST UNIT FOR SKID MOUNTING	950 HP	660 HP	1100 HP	660 HP

For more data on advertised products, use Readers' Service Cards, last page.

On these two pages you'll find a comparison of all the significant facts about gas engine compressors in the 375 to 950 horsepower range. We think you'll have to agree that Worthington's SLHC unit is the outstanding performer in its size range. Not only does it have 18% better fuel economy than the next nearest engine, but it also features self-sustained turbocharging, removable cylinder liners with cast-in water jacket, interchangeable power and compressor rods, and many other important engineering advances.

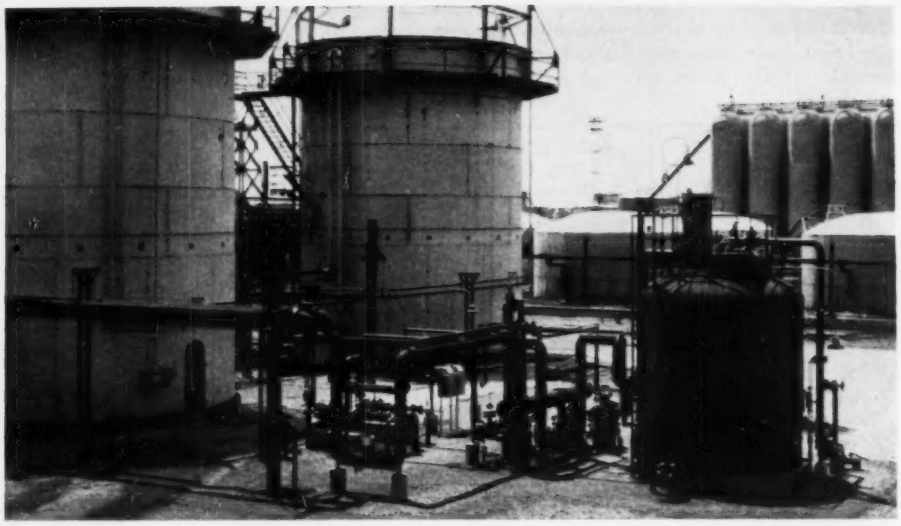
For complete details on the new SLHC engine compressor get in touch with your nearest Worthington district office. Or write to Worthington Corporation, Section 43-4, Harrison, N. J. In Canada: Worthington (Canada) Ltd., Brantfold, Ont.

WORTHINGTON

FEATURE	WORTHINGTON SLHC	MFR. A	MFR. B	MFR. C
MOUNT CYLINDERS ON BOTH SIDES	Yes	No	No	No
CYLINDER LINERS	Removable	Removable	NONE	NONE
INTERCHANGEABLE POWER AND COMPRESSOR RODS	Yes	Yes	No	No
SIDE BY SIDE CONNECTING RODS	 Yes	Yes	No	No
FRAME CONSTRUCTION	En-bloc	En-bloc	 Separate Cylinders	 Separate Cylinders
IGNITION	Twin	Single	Single	Single
RUNNING GEAR LUBRICATION	MANIFOLD CAST IN BASE	SEPARATE PIPE MANIFOLD	SEPARATE PIPE MANIFOLD	SEPARATE PIPE MANIFOLD
GASKET-FREE CYLINDER HEAD SEATS	YES	NO	NO	NO
RUNNING GEAR EASILY ACCESSIBLE	YES	NO	NO	NO

For more data on advertised products, use Readers' Service Cards, last page.

PRODUCT IMPROVEMENT WITH **PETRECO**



Compare the small, compact Petreco Electrofining Precipitator in the foreground with the large-diameter, twice-as-high open agitators.

Cities Service reduces oil-treating caustic from 15000 to 3400 lbs./month with ELECTROFINING precipitator*

Since the Cities Service Oil Company refinery in East Chicago, Indiana, replaced its two large air-blown agitators with an ELECTROFINING Precipitator, the caustic needed to treat burning oil has been reduced from 15000 pounds per month to 3400 pounds per month. This is possible because the intense caustic contact with the ELECTROFINING Precipitation Equipment enables *less caustic to do more work.*

OTHER IMPORTANT ELECTROFINING PRECIPITATION BENEFITS

■ *ELECTROFINING Precipitation Equipment Simplifies Waste Disposal.* When agitators were used, 15000 pounds of oil contaminated caustic had to be disposed of every month. The ELECTROFINING unit has reduced the amount to be disposed of to 3400 pounds per month. Since the ELECTROFINING unit is vapor-tight it permits no escape of oil vapors to the atmosphere as the agitators did.

■ *Requires Less Construction Material; Less Space.* Note the physical difference. The amount of sheet steel and pipe required for the construction of the agitators was many fold that used in the custom-built, virtually pre-fabricated ELECTROFINING Precipitator. The real estate occupied by the ELECTROFINING unit is only one-third the amount of space required by the agitators.

■ *Replaces Manual with Automatic Operation.* Agitator treatment is controlled by the judgment and experience of human operators. ELECTROFINING units are automatically controlled at all times to provide optimum treating efficiency as established by laboratory pilot-plant operation.

■ *Reduces Heating Requirement.* After agitation the oil had to be heated to 120°F. to remove water haze. The ELECTROFINING unit treats the oil at 85°F. and no after treating heat is required so that total fuel requirements are reduced.

Find out now how ELECTROFINING in your operation can save dollars and make sense. Write or call . . .

*ELECTROFINING *is a registered trademark of Petrolite Corporation.*

DT 59-1

PETROLITE CORPORATION

PETRECO DIVISION

3202 South Wayside Drive (P.O. Box 2546), Houston 1, Texas
1390 East Burnett Street (P.O. Box 7216), Long Beach 7, California

CANADA: Petrolite Corporation of Canada, Limited, 4528 Stanley Drive, Calgary, Alberta

ENGLAND: Petrolite Limited, Heathcoat House, 20, Savile Row, London W. 1.

VENEZUELA: South American Petrolite Corporation, Hotel Avila, Caracas

REPRESENTATIVES

BRAZIL: WERCO, Ltda., Avenida Rio Branco 57—s/1410-11, Rio de Janeiro

COLOMBIA: W. F. Faulkner, Calle 19, No. 7-30, Office 807, Bogota

ITALY: O. Wagner, 149 Via Nemorense, Apt. 1, Rome

JAPAN: Chiyoda Chemical Engineering and Construction Company, Ltd., Tokyo Bldg., No. 3, Marunouchi 2-Chome, Chiyoda-Ku, Tokyo

KUWAIT: F. N. Dahdah, Box 1713, Al Kuwait

MEXICO: R. E. Power, Sierra de Mijes, No. 125, Mexico D. F.

NETHERLANDS: F. E. C. Jenkins, Hoefbladlaan 134, The Hague

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HARSHAW CATALYSTS

are available in 6 forms:

TABLETED • EXTRUDED • GRANULAR
SPHERES • FLAKES • POWDERS

We'll assist you in developing the best and most economical catalyst for your needs. Our more than 20 years catalyst experience and acres of production and research facilities are ready to work for you. Harshaw produces carloads of catalysts every week—this capacity guarantees prompt shipment of your catalyst order.

PREFORMED CATALYSTS
to fit special process requirements

Hydroforming • Cyclization • Oxidation • Dehydrogenation
Dehydration • Desulphurization • Alkylation • Hydrogenation,
Hydro treating • Chlorination

CATALYTIC CHEMICALS SUPPLIED BY HARSHAW

Aluminum Nitrate	Metallic Soaps (Cobalt, Manganese)	
Manganese Nitrate Solution	Cobalt Nitrate	Copper Nitrate
Nickel Carbonate	Nickel Formate	Nickel Nitrate
Nickel Sulfate	Sodium Methoxide	Zinc Nitrate

Our experienced technical staff will assist you in developing the best and most economical catalyst. If you have a catalytic process in the development or production stage, a discussion with us may prove beneficial.

Write for Free Book

HARSHAW

THE HARSHAW CHEMICAL CO.
Chicago • Cincinnati • Cleveland • Detroit
Houston • Hastings-On-Hudson, N.Y. • Los Angeles
Philadelphia • Pittsburgh

For more data on advertised products, use Readers' Service Cards, last page.

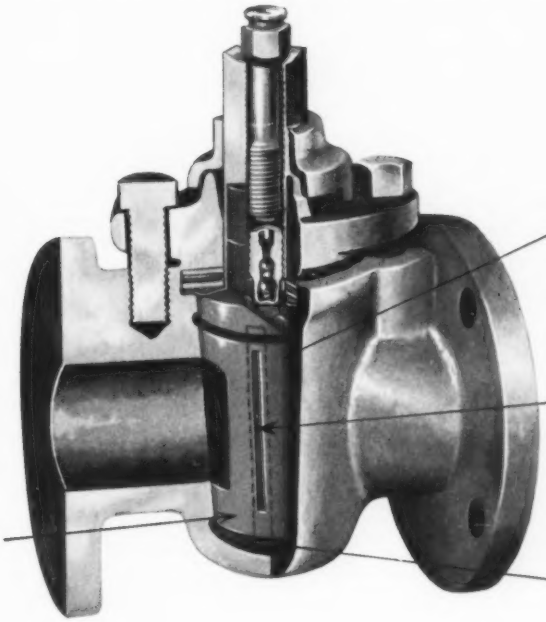
ROCKWELL- Nordstrom **VALVES**

Just a little leak?

Little leaks . . . unless they're stopped . . . sink big ships. And valves with little leaks cost industry millions of dollars every year. In terms of dollars and cents and human lives, there's no such thing as a "little leak."

Valves that leak "just a little" mean ever-increasing product loss, product contamination, or hazards. That's why wherever the safety, precision or economy of flow control dictates that even little leaks can't be tolerated, you'll see Rockwell-Nordstrom lubricated plug valves.

LUBRICANT-SEALED FOR POSITIVE SHUT-OFF


Seats never exposed to line . . . permanent, positive shut-off.
Pressurized lubricant in Sealdport® grooves forms impenetrable seals against leakage . . . lubricant is instantly replaceable seat that can't "wear out."
Solid tapered plug is rugged and self-seating.
Pressurized lubricant hydraulically cushions plug for instant, quarter-turn closure.

Rockwell-Nordstrom is the original and world's most complete line of lubricated plug valves with sizes from ¾" to 36" and pressures to 15,000 lb. Available at leading oil field and industrial supply houses everywhere. For details, see your supplier or write: Rockwell Manufacturing Company, Pittsburgh 8, Pa. If you live outside the U. S. A., write: Rockwell International Division, Pittsburgh 8, Pa.

®Reg. T.M. Rockwell Manufacturing Company

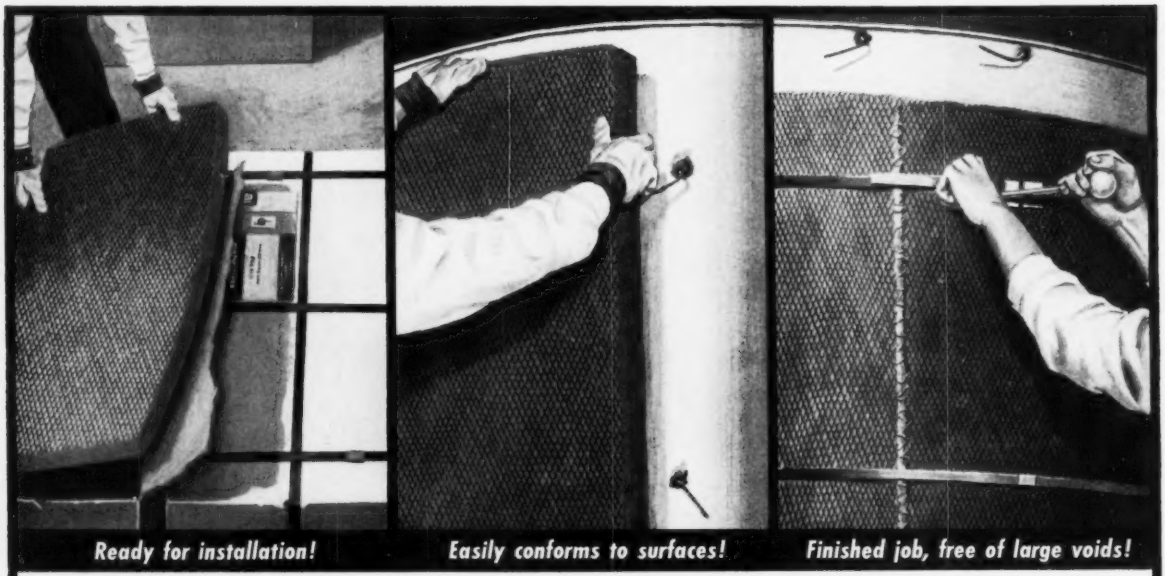
ROCKWELL-Nordstrom VALVES

another fine product by

ROCKWELL

FACTORY FABRICATED TO RIGID SPECIFICATIONS!

EAGLE-PICHER BLANKET INSULATION



Ready for installation! *Easily conforms to surfaces!* *Finished job, free of large voids!*

- Copper bearing steel laths, bound by uniformly spaced soft-drawn galvanized tie wires, keep blankets firm but flexible.
- Eagle-Picher mineral wool evenly dispersed over entire insulating area of each blanket.
- Completely free of large voids usually found in field-made blankets where insulation is simply packed in place.
- Smooth edges butted tightly together eliminate cracks and loose joints.
- Quickly applied to flat or slightly curved surfaces of any large equipment—or cut to fit irregular areas.
- Maximum thermal efficiency at temperatures as high as 1200 F.

Eagle-Picher produces a complete line of industrial insulations for all temperatures from below Zero to over 2000 F.

FREE SAMPLE!

Write today!

Eagle-Picher Blanket Insulation conforms to Commercial Standard CS-117-49.

Since 1843

EAGLE PICHER

EAGLE-PICHER

The Eagle-Picher Company • Dept. PR-6, Cincinnati 1, Ohio

(Member of Industrial Mineral Fiber Institute)

Drastic reduction of heat loss with **PABCO PRECISION-MOLDED CALTEMP** a Calcium Silicate Insulation

When vapors or liquids are conveyed or held at temperatures up to 1900° F.—when equipment is operated to high heat levels—Pabco insulations cut heat losses to absolute minimums. "Precision-Molded" by a patented process, Pabco's Caltemp and 85% Magnesia pipe and block insulations control temperatures within close tolerances. For data on technical advantages, case histories, or engineering consultation, write . . . or call a Pabco insulation engineer.

INSULATION GUIDE

Temperature	Recommended Pabco Insulation		
to 550°	85% Magnesia pipe covering	block	cement
to 1200°	Caltemp pipe covering	block	cement
to 1500°	Prasco 15 C pipe covering	block	cement
to 1900°	Prasco 19 C	block	

PABCO

INDUSTRIAL INSULATIONS DIVISION

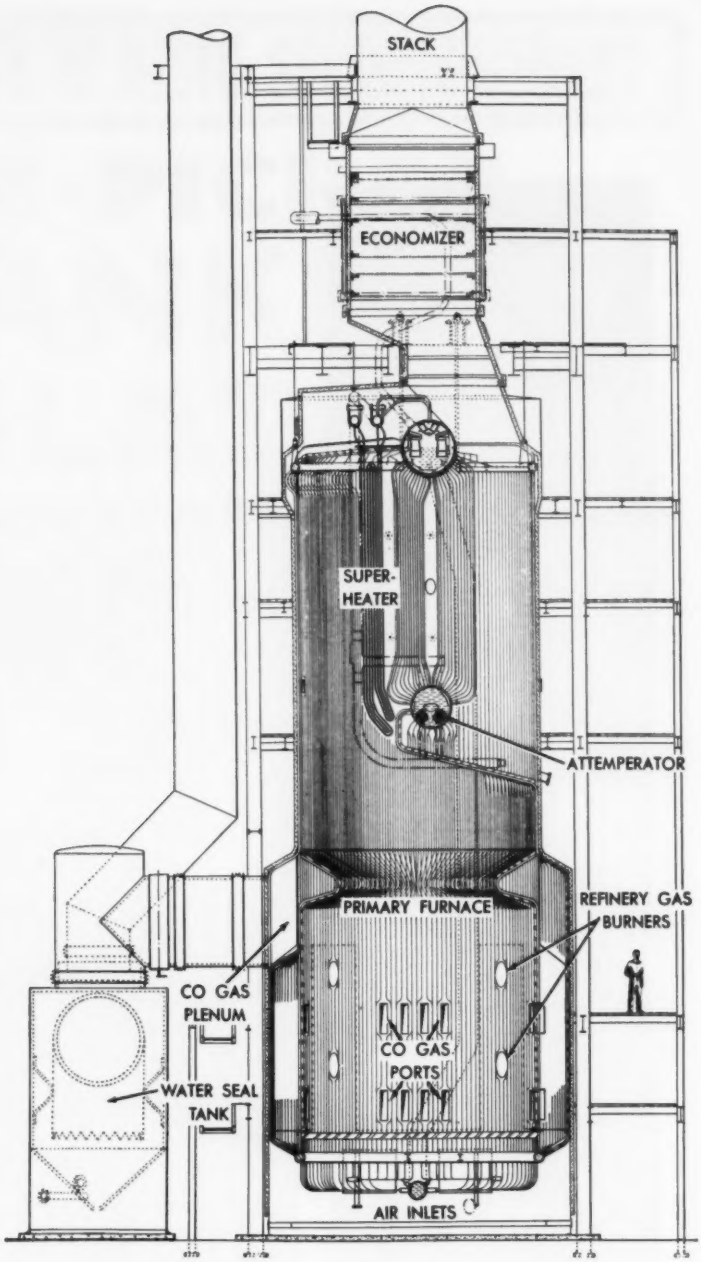
Fibreboard Paper Products Corporation

San Francisco 19 • Chicago 54

Houston 4 • New York 16 • Los Angeles

Refinery Report: **CO 15**

Converting Waste to profit for SOHIO



This is a Babcock & Wilcox CO Boiler.

It was purchased by The Standard Oil Company (Ohio) for their ultra-modern, completely-integrated refinery in Toledo, Ohio.

It is designed to use the heat in waste CO gases from the cracking unit to generate steam for the refinery's power and process needs.

It does just that. Hour after hour. Day after day. Week after week. Dependably and efficiently.

It will save enough fuel to pay for itself in less than 3 years.

Probably, a B&W CO Boiler can do the same for your refinery.

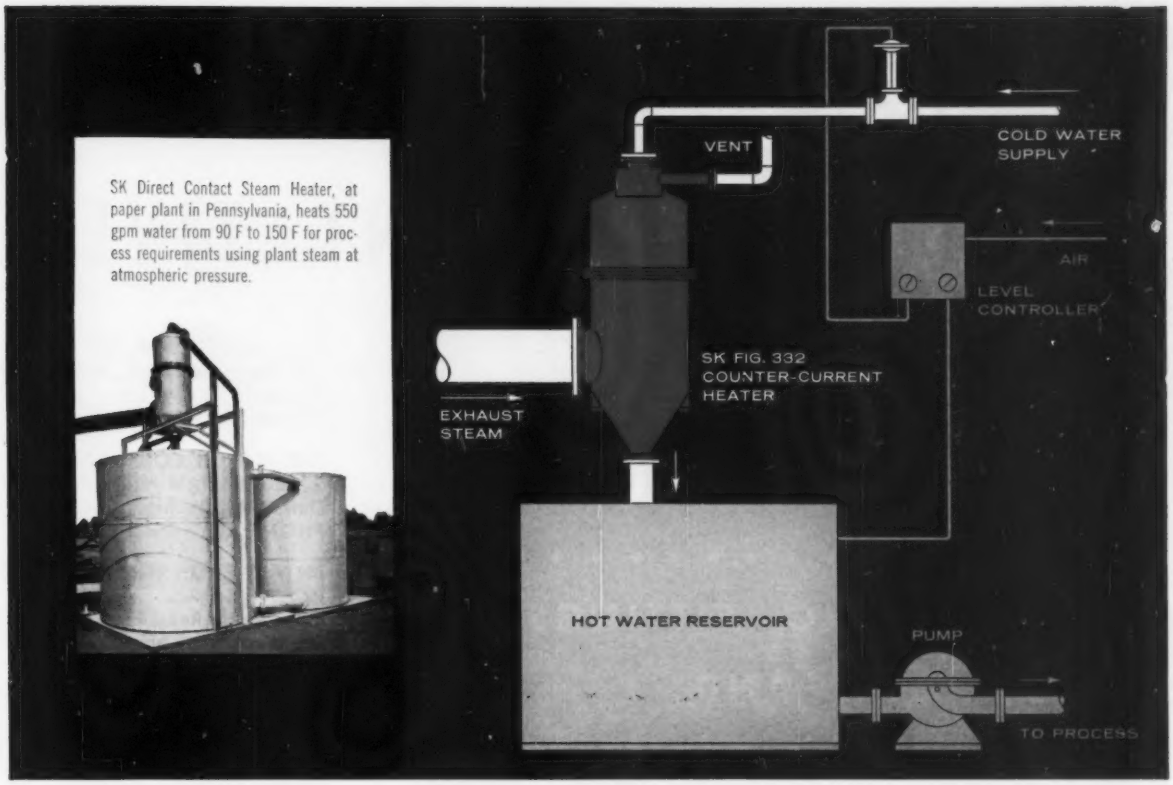
Find out. Write us today. The Babcock & Wilcox Company, Boiler Division, Barberton, Ohio.

CO-103

B&W

THE BABCOCK & WILCOX COMPANY

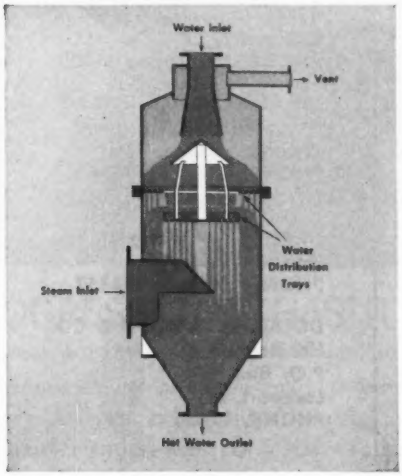
BOILER DIVISION


SK Direct Contact Steam Heater, at paper plant in Pennsylvania, heats 550 gpm water from 90 F to 150 F for process requirements using plant steam at atmospheric pressure.
VENT
COLD WATER SUPPLY
AIR
LEVEL CONTROLLER
SK FIG. 332 COUNTER-CURRENT HEATER
EXHAUST STEAM
HOT WATER RESERVOIR
PUMP
TO PROCESS

FOR HOT WATER IN LARGE QUANTITIES

use SK Direct Contact Steam Heaters

Sectional drawing of SK Fig. 332
Direct Contact, High Capacity, Steam Heater



SK Direct Contact Steam Heaters are designed to provide large quantities of hot water, or other liquid, for plant or process use. They do this by using plant exhaust steam (at low pressure or at vacuum to 15 in. Hg) to heat the water which is then delivered to a tank or reservoir.

To users, these high capacity heaters offer specific, worthwhile advantages. They are simple in design, have no moving parts. Heating, by condensation of steam in the liquid, is very efficient, continuous, and fast. A temperature rise of 130 F is possible with most of these units. Semi-solids in the liquid are handled without difficulty. Costs are reasonable and the heaters require little maintenance. Capacity can be just about any reasonable amount desired, since capacity is determined by heater size and SK has not established any maximum. Although cast iron and fabricated steel are standard materials of construction, other special materials can be used when required.

The counter-current unit pictured above and at left is one of four types made by SK. This particular heater and all of the other types are described in detail in Bulletin 3A-HC which includes application information and data on sizes, dimensions, and capacities. Copies of Bulletin 3A-HC are available immediately on request. Send for a copy.

JET APPARATUS: Ask for Condensed Bulletin J-1.
ROTAMETERS & FLOW INDICATORS: Ask for Condensed Bulletin M-1.
VALVES: Ask for Condensed Bulletin V-1.
HEAT TRANSFER APPARATUS: Ask for Condensed Bulletin HT-1.
GEAR PUMPS: Ask for Bulletin G-1.

Schutte and Koerting
COMPANY
MANUFACTURING ENGINEERS SINCE 1876
2257 State Road, Cornwells Heights, Bucks County, Pa.

For more data on advertised products, use Readers' Service Cards, last page.

...See THESE SALES REPRESENTATIVES WITH YOUR FABRICATION SPECIFICATIONS

TUBING – FITTINGS
AND
SPECIALTIES

FELKERWELD

FOR ENDURANCE
on such metals as
Stainless Steel,
Stainless Clad Steel,
Inconel, Monel,
Nickel, Copper,
and Aluminum Bronze

OR COMMUNICATE WITH US DIRECT . . .

FELKER BROTHERS MANUFACTURING CO.
PHONE FUlton 4-3121 - TWX 8912 MARSHFIELD, WIS.

E. P. BIEVER, MFR. REP.
254 Paces Ferry Rd., N.E.
Atlanta 5, Ga.
PHONE: CE 7-9464

THE MARCH CORPORATION
23100 W. Eight Mile Rd.
Detroit 41, Michigan
PHONE: KEnwood 3-3946

METALS ENGINEERING CO.
Ray W. Mercier
4350 Ridge Road West
Rochester 13, N.Y.
PHONE: GLenwood 3-1266

METALS ENGINEERING CO.
Robert Hutchinson, Jr.
3 South Main Street
Natick, Mass.
PHONE: OLympic 3-7230

METALS ENGINEERING CO.
Robert Soracco
122 Post Road
Fairfield, Conn.
PHONE: CLearwater 9-9505

EDWIN J. ORGERON
82 W. Claiborne Sq.
Chalmette, La.
PHONE: EDgewood 1-4095

LEE REDMAN EQUIPMENT CO.
610 South 19th Avenue
Phoenix, Arizona
PHONE: ALpine 8-3794

T. D. SANDELIUS CO.
6122 St. Augustine St.
Houston, Texas
PHONE: JAckson 6-4357

DOUGLAS ROBBINS & CO.
Hal Bogner
P.O. Box 55
Lockport, Ill.
PHONE: 1743

PROGRESS, TOO, HAS ITS GOLDEN RULE...

It's the *teamwork* of men capable of producing progress—refiners and Cyanamid chemists.

This teamwork has produced concrete benefits. It helped bring the development of one of the first synthetic fluid cracking catalysts. It helped produce the first fully regenerative platinum reforming catalyst. It can help you meet the almost-relentless demands for ever superior fuels.

Behind Cyanamid's service as a major catalyst producer are its unlimited resources as a major chemical producer. Cyanamid's man with the golden rule can place at your disposal vast research and development facilities.

Basic in Catalyst Chemistry

CYANAMID

AMERICAN CYANAMID COMPANY
REFINERY CHEMICALS DEPARTMENT
30 Rockefeller Plaza, New York 20, N. Y.

colossus in stainless

...world's largest stainless steel plates ready for processing at Carlson

SOMETIMES Carlson service is a cooperative venture that gets practically impossible jobs done. The processing and finishing of these, the world's largest stainless steel plates, is an example of such teamwork.

As this was a "first time" job, the most careful planning and coordination had to be exercised. Oversize ingot molds and a 70-ton capacity furnace had to be used. It took the country's largest plate mill to roll the ingots to slabs, the slabs to plates. The finished plates, cut-to-shape by Carlson specialists, met every customer requirement.

These huge plates, of Type 304 stainless steel, were made to Specification A-240 Grade S (ASTM A240-T). Each plate weighed over 49,000 pounds; one measured 461″ x 179″ x 2″; the other 451″ x 184″ x 2″. Destined for a nuclear application, these plates were flame-cut and abrasive-cut to make two half-circles. The entire order totaled nearly 100,000 pounds.

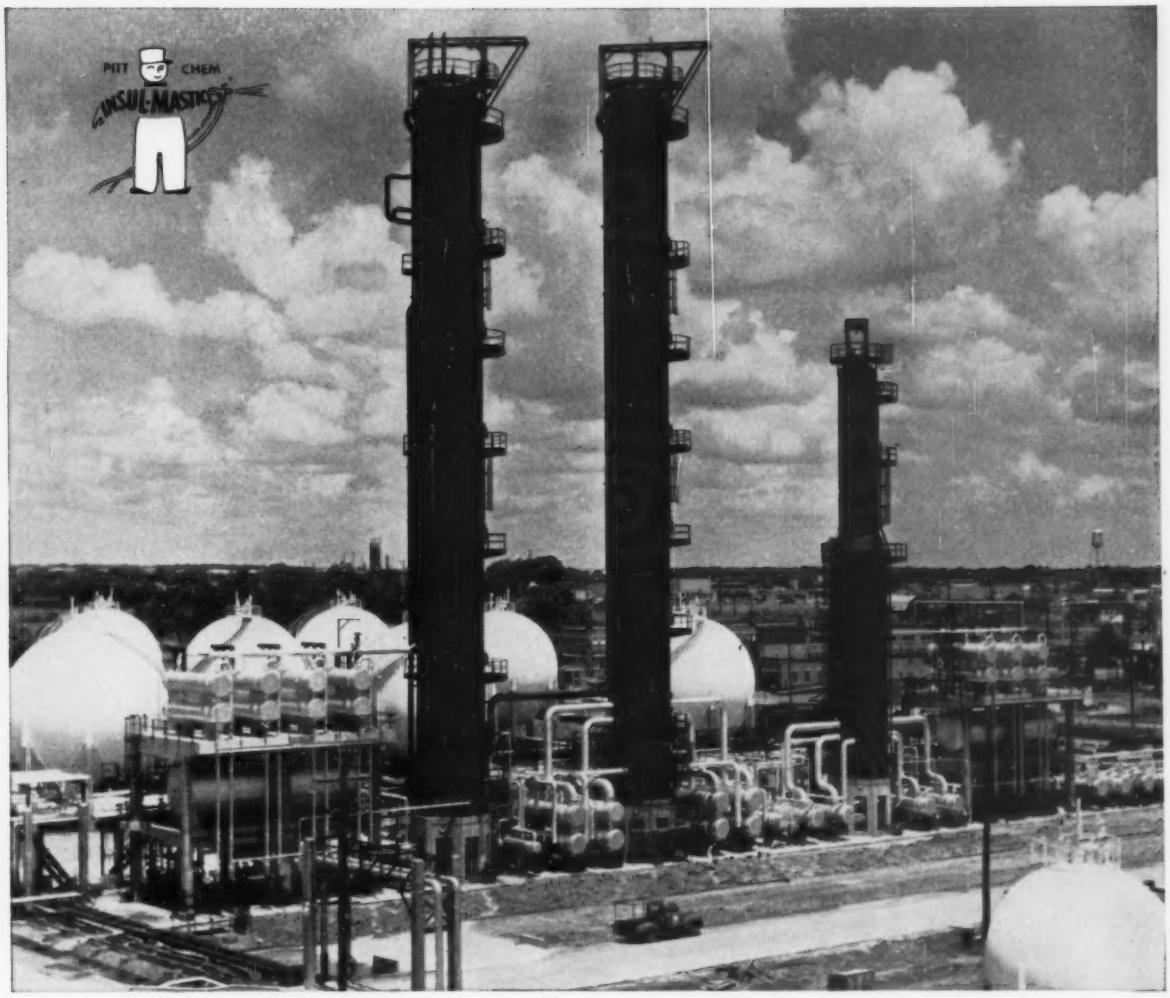
Cooperation made this "colossus" a success—cooperation under the knowing eyes of Carlson specialists. This same team is ready to work on your order. We invite you to write, wire or phone for further information.

G.O.CARLSON Inc.

Stainless Steels Exclusively

136 Marshalton Road
THORNDALE, PENNSYLVANIA
District Sales Offices in Principal Cities

PLATES • PLATE PRODUCTS • HEADS • RINGS • CIRCLES • FLANGES • FORGINGS • BARS and SHEETS (No. 1 Finish)



"Double Assault" Corrosion Attack Stopped With PITT CHEM *Insul-Mastic*

A COMBINATION of chemical corrosion and salt spray posed a tough corrosion problem at this butane plant, one that demanded far more than ordinary maintenance protection.

A *service-proven* Pitt Chem *Insul-Mastic* coating, 4010, was selected for the job. Results after *10 years* of service: More than adequate protection.

Insul-Mastic's unique Gilsonite-asphalt formulation provides a coating that stops not only moisture vapor penetration but most common industrial fumes and spillage, as well. Unlike ordinary asphalt coatings, Pitt Chem *Insul-Mastic*, with its high Gilsonite content, is able to withstand extremes of heat and cold, expansion and contraction, and moisture and dryness.

Specify Pitt Chem *Insul-Mastic* for *your* next vaporseal, corrosion-proofing job. You'll get dependable, economical protection, proven in over two decades of service.

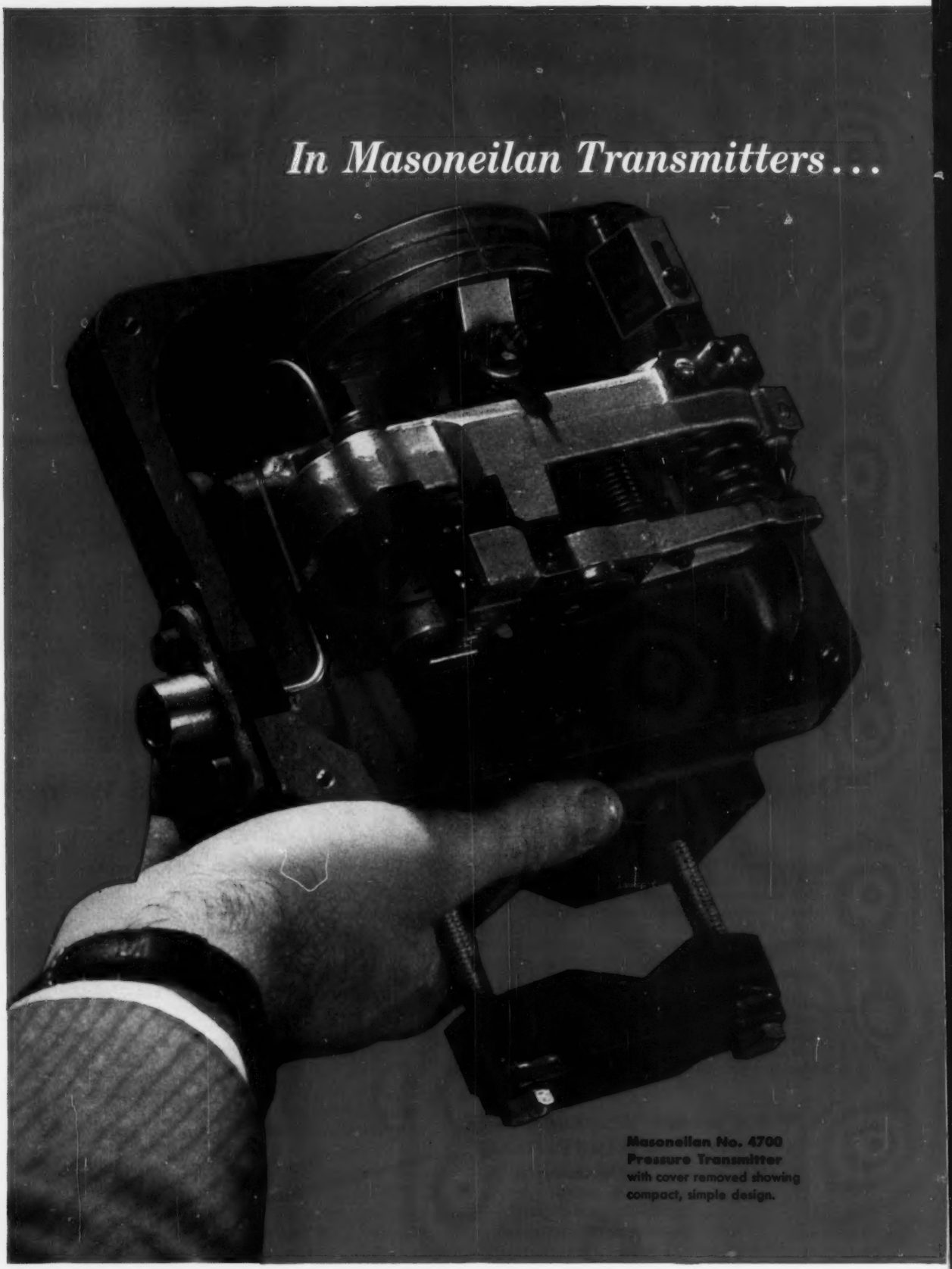
Pitt Chem *Insul-Mastic* Coatings are available through leading industrial distributors. See the "Yellow Pages."

★ PITT CHEM "Insul-Mastic"® Gilsonite-Asphalt Coatings
★ PITT CHEM "Tarset"® Coal Tar-Epoxy Resin Coatings
★ PITT CHEM "Tarmastic"® Coal Tar Coatings

PROTECTIVE COATINGS • COAL CHEMICALS • PLASTICIZERS • ACTIVATED CARBON • COKE • CEMENT • PIG IRON • FERROMANGANESE

For more data on advertised products, use Readers' Service Cards, last page.

In Masoneilan Transmitters . . .



Masoneilan No. 4700 Pressure Transmitter with cover removed showing compact, simple design.

Important Design Features Give You Top Performance

Accurate, dependable pneumatic transmission of pressure or temperature is assured by these compact, lightweight, force-balance transmitters. In addition to the advantages inherent in this class of instruments, the Masoneilan design offers a number of features which make them outstanding.

1. **Balanced beam permits mounting in any position without zero shift; permits changing position at will without rezeroing.**
2. **High accuracy — for example a 100F span temperature transmitter set for 0-100F is accurate within ±0.5°.**
3. **Locked span-location setting is unaffected by vibration — will not shift.**
4. **High capacity, balanced relay speeds transmission; permits longer transmission lines.**
5. **Derivative unit and integral receiver gauge may be added without tubing and without removing cover.**
6. **Unit subassembly construction permits changeover from temperature to pressure (or vice versa), or change of span, without disturbing beam.**

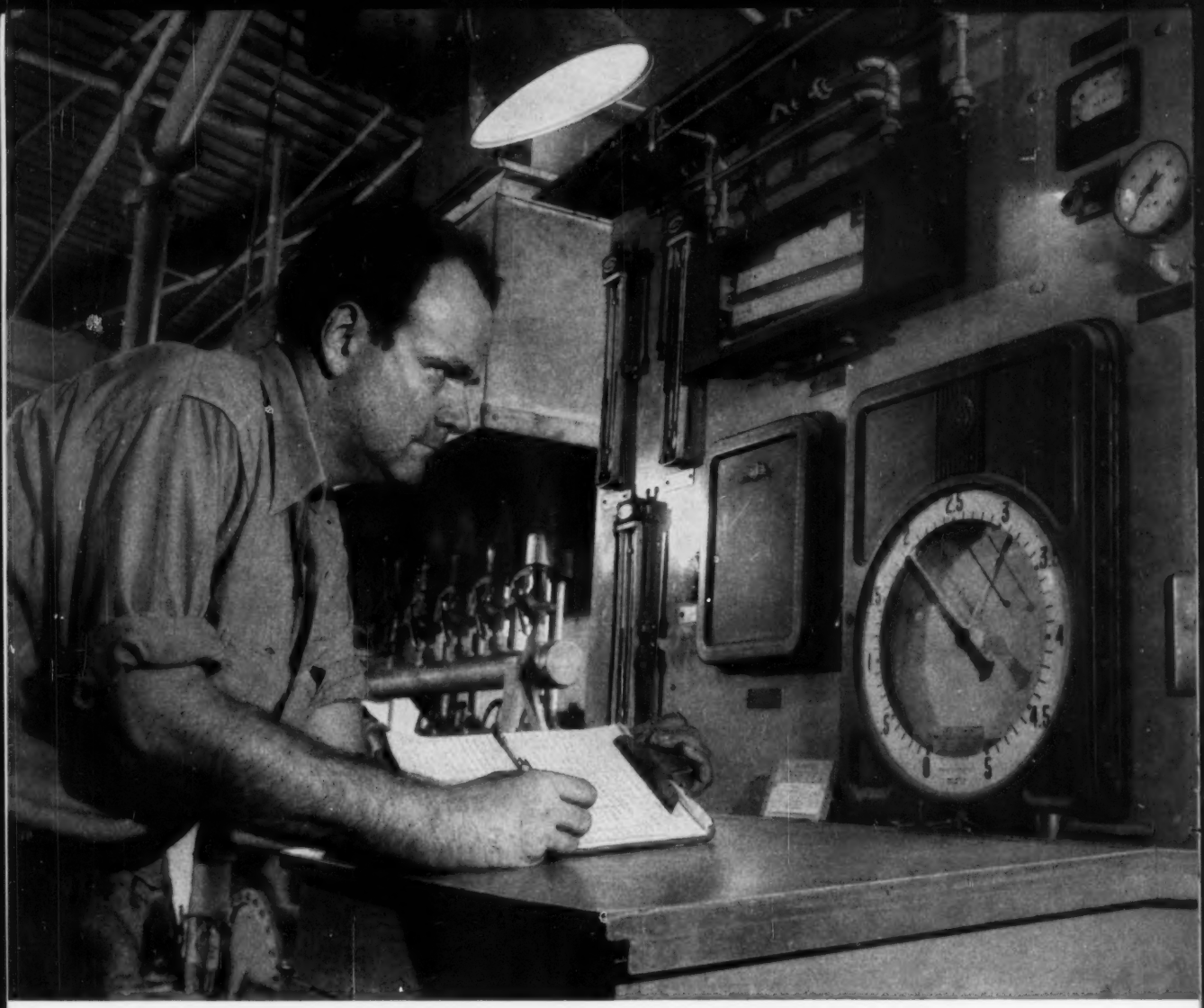
Simplicity and unit construction, plus compact ruggedness, make these transmitters very easy to install and maintain. This, plus moderate first cost, makes them a topnotch investment in improved measurement and control. Send for your copy of bulletin.

MASON-NEILAN

A Division of Worthington Corporation
51 NAHATAN STREET, NORWOOD, MASSACHUSETTS
District offices or Distributors in principal cities in U.S.
In Canada: Mason-Neilan, Division of Worthington (Canada), Ltd.

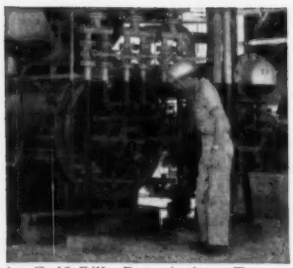
MN9-9

For more data on advertised products, use Readers' Service Cards, last page.



For tested generator performance . . .

Come to Kemp



At Gulf Oil's Port Arthur, Texas refinery, purging inerts are supp.ied by Kemp Generator and Kemp Dryer working as a team. The units produce 30,000 SCFH for a bountiful and easily controlled supply at low cost.

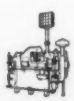
Tested . . . and proved! Factory tested with rigid component checks, field tested by Kemp engineers at installation, and time tested by years of actual use. Proved that Kemp Inert Gas Generators are built to last, built to produce, built to be accurate.

At the heart of every Kemp Generator is the Kemp Industrial Carburetor, uncomplicated in concept, yet outstanding in performance. It provides sensitive and accurate control of inert analysis. A quick setting of the calibrated dial insures delivery of an unvarying mixture, regardless of line demands.

And Kemp design—rugged, simple, and sturdy —means that maintenance and attendance requirements are kept to a bare minimum. Kemp Inert Gas Generators stand up under the toughest conditions, yet produce with complete dependability.

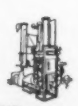
Your Kemp Representative is listed in *Chemical Engineering Catalog*. Give him a call for more information, or write direct for Bulletin I-10. THE C. M. KEMP MFG. CO., 405 East Oliver St., Baltimore 2, Md.

Convection Dryers



Atmos Generators

KEMP OF BALTIMORE

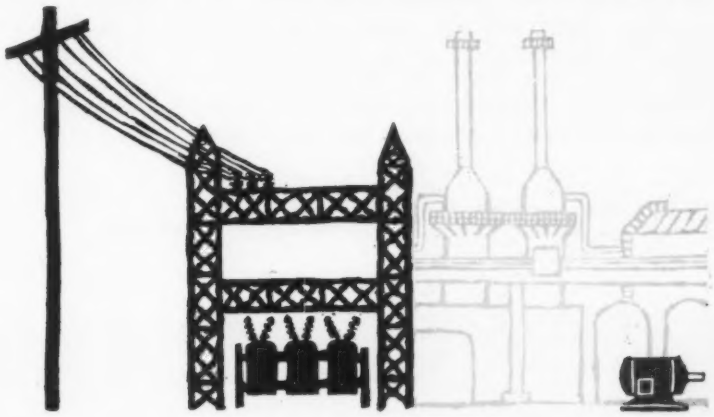


Nitrogen Generators

Oriad Dryers

plan now to

POWER-UP FOR PROFIT ELECTRICALLY



Sinclair Refining did: increased production, improved products, reduced costs

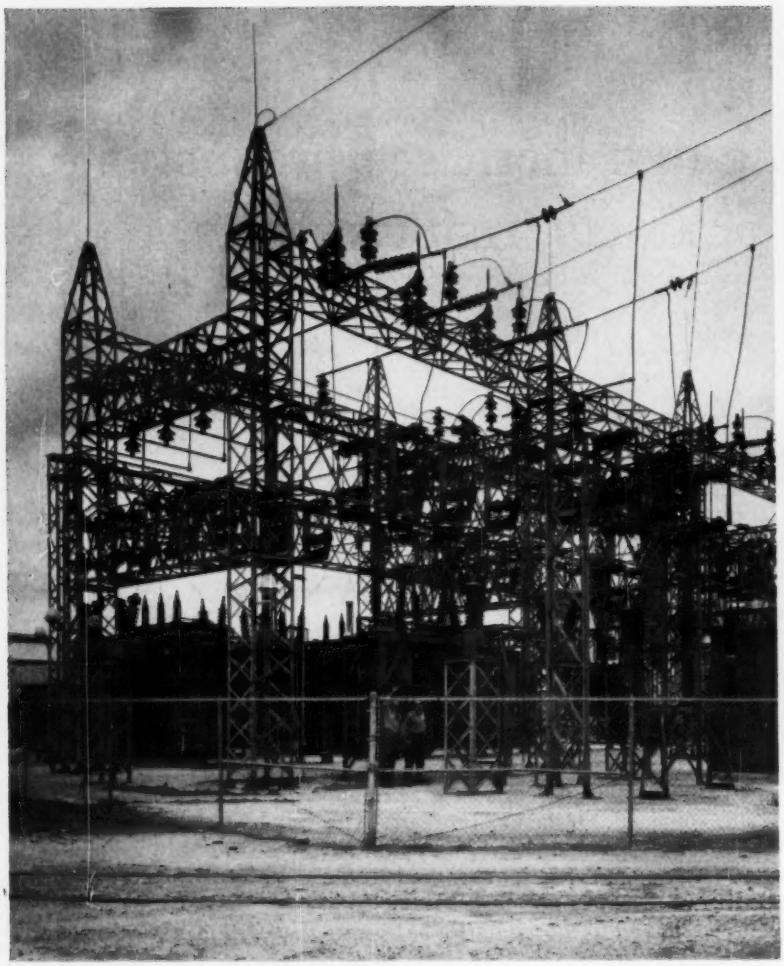
When Sinclair Refining modernized and expanded their Houston refinery, production increased and product quality improved. All this was accomplished through a carefully planned Power-Up program. The reliability of present-day electrical equipment and power supply minimized the amount of stand-by equipment needed.

You will need more capacity to meet the 40% increase in demand for goods by 1965. Be sure that your electrical equipment is engineered to produce earnings as well as output. See how Westinghouse helped Sinclair Refining to Power-Up.

YOU CAN BE SURE...IF IT'S **Westinghouse**

For more data on advertised products, use Readers' Service Cards, last page.

here's how Sinclair Refining



Main substation with two incoming 66-kv power lines is equipped with Westinghouse switchgear and transformers. Continuity of service is assured through the use of this dual feed to the refinery.

Relaying panels for protection of two incoming 66-kv lines, showing pilot wire and associated relays. These high-speed relays provide superior circuit protection by minimizing equipment damage and provide service continuity.

For more data on advertised products, use Readers' Service Cards, last page.

POWERED-UP with Westinghouse

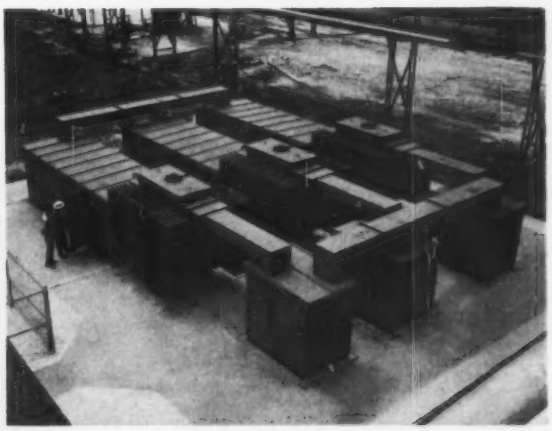
Expansion and modernization at Sinclair's Houston refinery were carried out in two phases. Initially, a fluid catalytic cracking unit was added to expand the plant's capacity. Subsequently, two HDS (Hydrodesulphurization) units were added to improve the product quality.

The complete electrical system from the incoming lines to the motors was designed and coordinated to give an integrated electrical supply tailored to the specific requirements. This approach provided the most economical system to meet the reliability and continuity of service demanded.

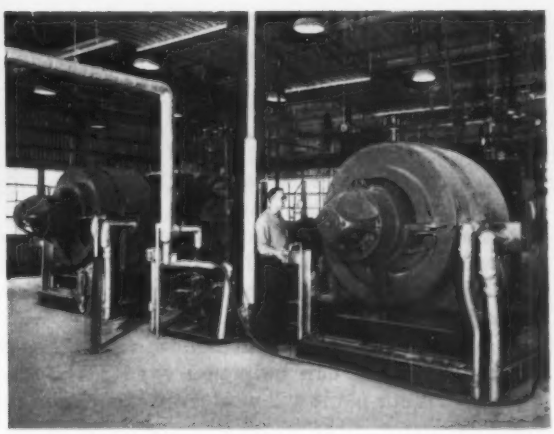
J-96131

YOU CAN BE SURE...IF IT'S Westinghouse

The refinery is served by three power transformers through three outdoor high-voltage switchgear assemblies interconnected by tie bus. Protective relaying system permits fast change-over, insures service even with power interruptions.



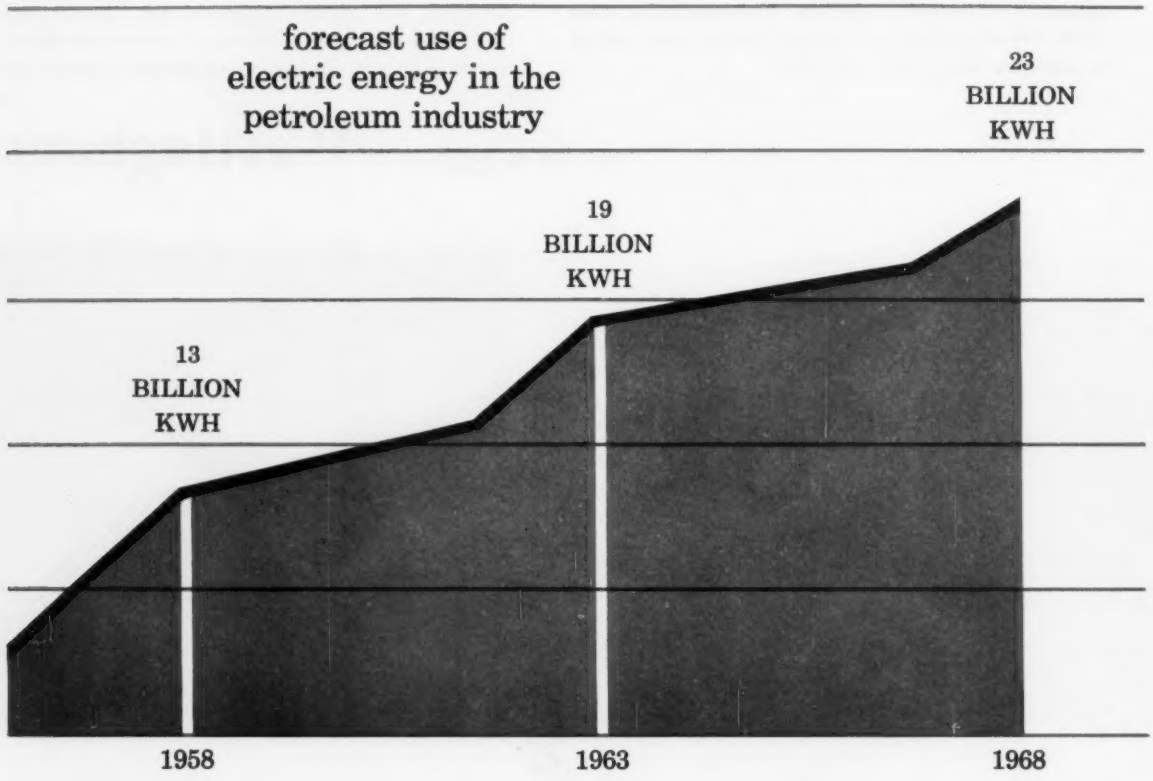
Unit substation with three 5000-kva transformers. Availability of alternate transformers and breakers provides the ultimate in reliability.



Large Westinghouse synchronous motors with Thermalastic® insulation which assures trouble-free operation and longer life. They are driving cooling water circulation pumps.

For more data on advertised products, use Readers' Service Cards, last page.

here's why you should plan now to
POWER-UP FOR PROFIT ELECTRICALLY



To stay competitive, you will be investing in a tremendous increase in electric power equipment. Be sure it is engineered to produce profits.

Greater use of electrical energy and up-to-date electrical equipment can help you get a better return on your investment through improved operations. In your plant it may be higher capacity machinery, more efficient equipment, or specially engineered controls.

Whatever the need, maximum use of low-cost kilowatthours can help you earn satisfactory profits. Your plant will need more capacity to meet the forecast 40% increase in the demand for goods by 1965.

Be sure—like Sinclair Refining—that your electrical equipment is engineered to produce earnings as well as output. Call your Westinghouse representative or your electric utility power sales engineer. They can tell you the electrical steps you can take *now* to start a Power-Up program in your plant. J-96131

YOU CAN BE SURE... IF IT'S **Westinghouse**

WATCH "WESTINGHOUSE LUCILLE BALL-DESI ARNAZ SHOWS" CBS TV MONDAYS

Could your gasoline pass the desert storage test?

Two years in "blitz" cans under the extreme temperature of a Southern California desert is a tough test of gasoline inhibitor effectiveness.

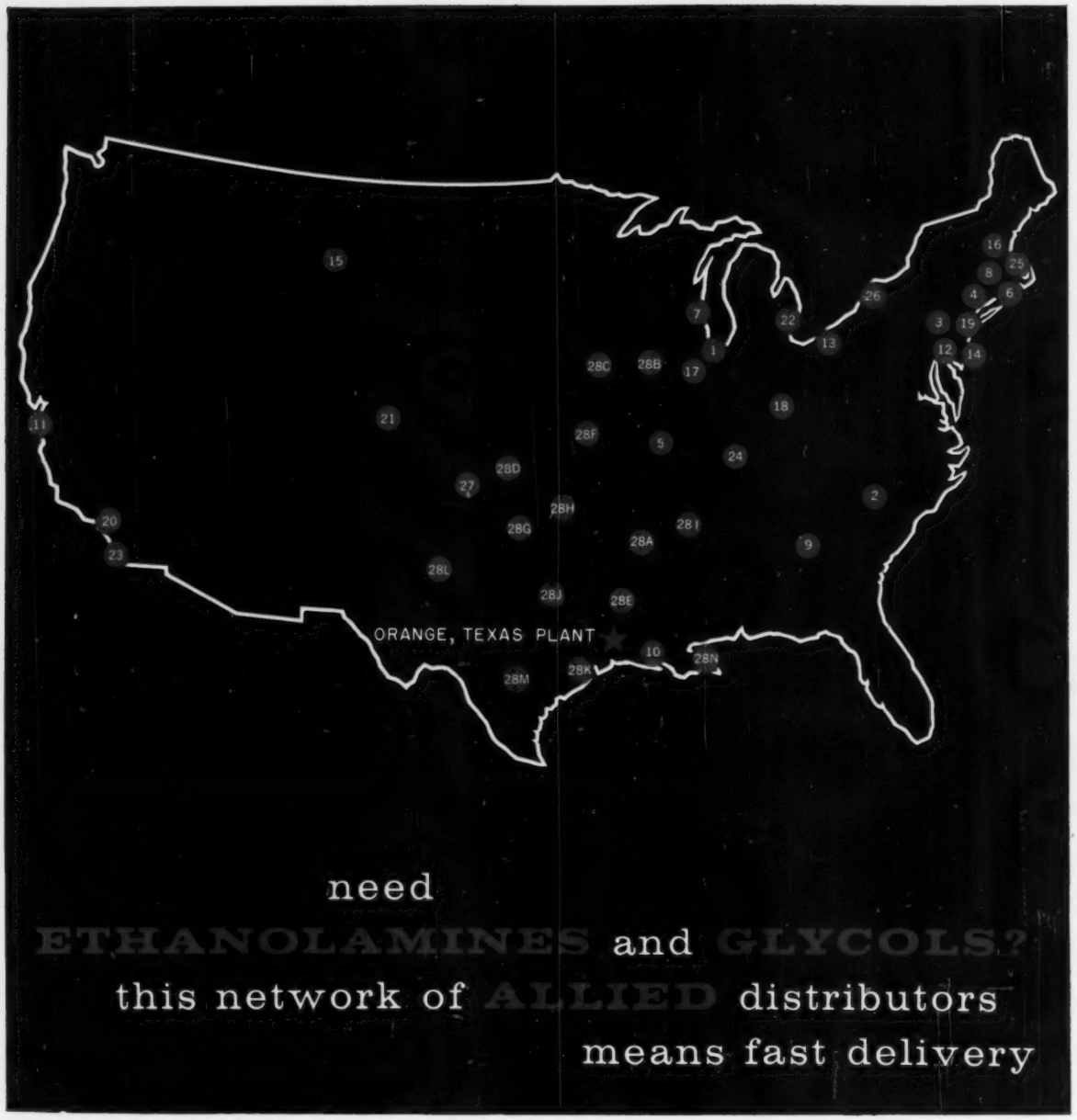
Koppers engineers have data compiled on six commercial gasolines meeting military requirements that were given such a test. Quantitative records of Cu dish gum, ASTM gum, ISD gum, peroxide number, and actual precipitates of these gasolines—at five different inhibitor levels with three popular inhibitors—clearly indicate the superiority of DBPC® Antioxidant, Koppers' inhibitor widely used by petroleum refiners.

May we make an appointment to review these test results with you? Please write, on business letterhead, to Koppers Company, Inc., Tar Products Division, Specialty Chemicals Section, Pittsburgh 19, Pa.

KOPPERS®

SPECIALTY CHEMICALS

TAR PRODUCTS DIVISION



need ETHANOLAMINES and GLYCOLS? this network of ALLIED distributors means fast delivery

Wherever you are, chances are there's a distributor of Allied ethanolamines and glycols nearby. To serve you promptly and economically, local drum stocks are maintained by the distributors listed at right. Drum and tank car quantities are also available from Allied's Orange Texas plant. Shouldn't you make a note right now of the source nearest you?

1. **Acid Products Co., Inc.**—Chicago, Ill.
2. **Acme Soap & Chemical Co.**—Charlotte, N. C.
3. **Aetna Color & Chemical Co.**—East Paterson, N. J.
4. **Apothecaries Hall Co.**—Waterbury, Conn.
5. **Harry A. Baumstark & Co.**—St. Louis, Mo.
6. **T. H. Baylis Co.**—Providence, R. I.
7. **Benlo Chemicals**—Milwaukee, Wisc.
8. **Chemical Sales & Service Co.**—Worcester, Mass.
9. **Chemical Services, Inc.**—Atlanta, Ga.
10. **Coastal Chemical Co.**—Abbeville, La.
11. **Cole & De Graf**—San Francisco, Calif.
12. **Geo. S. Coyne Chemical Co.**—Philadelphia, Pa.
13. **Crowley-Thompson Chemical Co.**—Cleveland, Ohio
14. **Delarich Corp.**—Delawanna, N. J.
15. **Dyce Sales & Engineering Service Co.**—Billings, Mont.
16. **Freeport Chemical Distributors**—Cambridge, Mass.
17. **Great Lakes Chemical Co.**—Cicero, Ill.
18. **Herbert Chemical Co.**—Cincinnati, Ohio
19. **Independent Chemical Co.**—Brooklyn, N. Y.
20. **Los Angeles Chemical Co.**—South Gate, Calif.
21. **Mine & Smelter Supply Co.**—Denver, Colo.
22. **O'Connor Chemicals, Inc.**—Detroit, Mich.
23. **Pacific Polymers**—Hawthorne, Calif.
24. **P B & S Chemical Co.**—Henderson, Ky.
25. **Plyco Products, Inc.**—E. Boston, Mass.
26. **Riverside Chemical Co.**—No. Tonawanda, N. Y.
27. **Southwest Gas Equipment Co.**—Liberal, Kan.
28. **Thompson-Hayward Chemical Co.** (All offices listed below are Thompson-Hayward)

28A—No. Little Rock, Ark. **28B**—Davenport, Ia. **28C**—Des Moines, Ia. **28D**—Wichita, Kan. **28E**—Shreveport, La. **28F**—Kansas City, Mo. **28G**—Oklahoma City, Okla. **28H**—Tulsa, Okla. **28I**—Memphis, Tenn. **28J**—Dallas, Texas. **28K**—Houston, Texas. **28L**—Lubbock, Texas. **28M**—San Antonio, Tex. **28N**—New Orleans, La.

BASIC TO AMERICA'S PROGRESS

Allied Chemical

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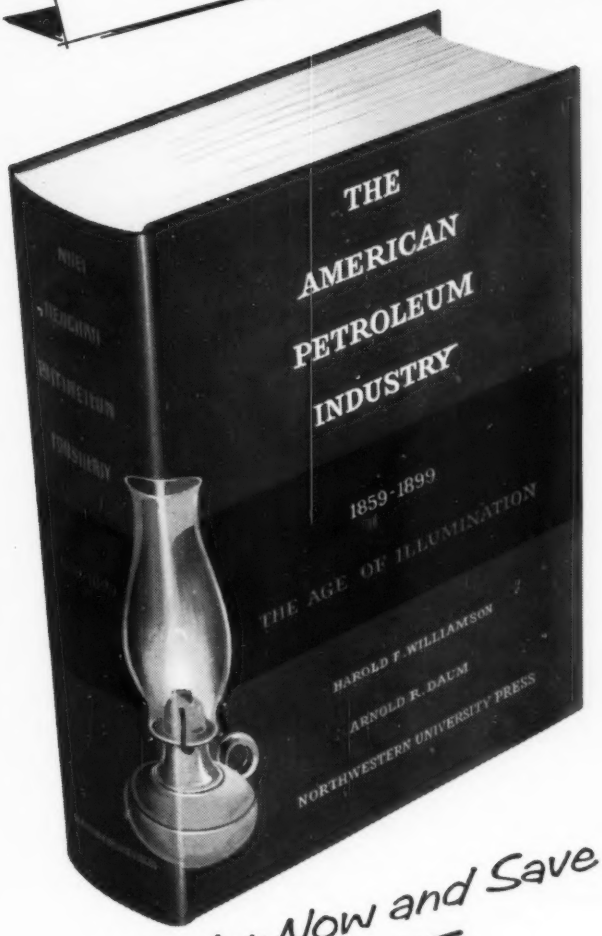

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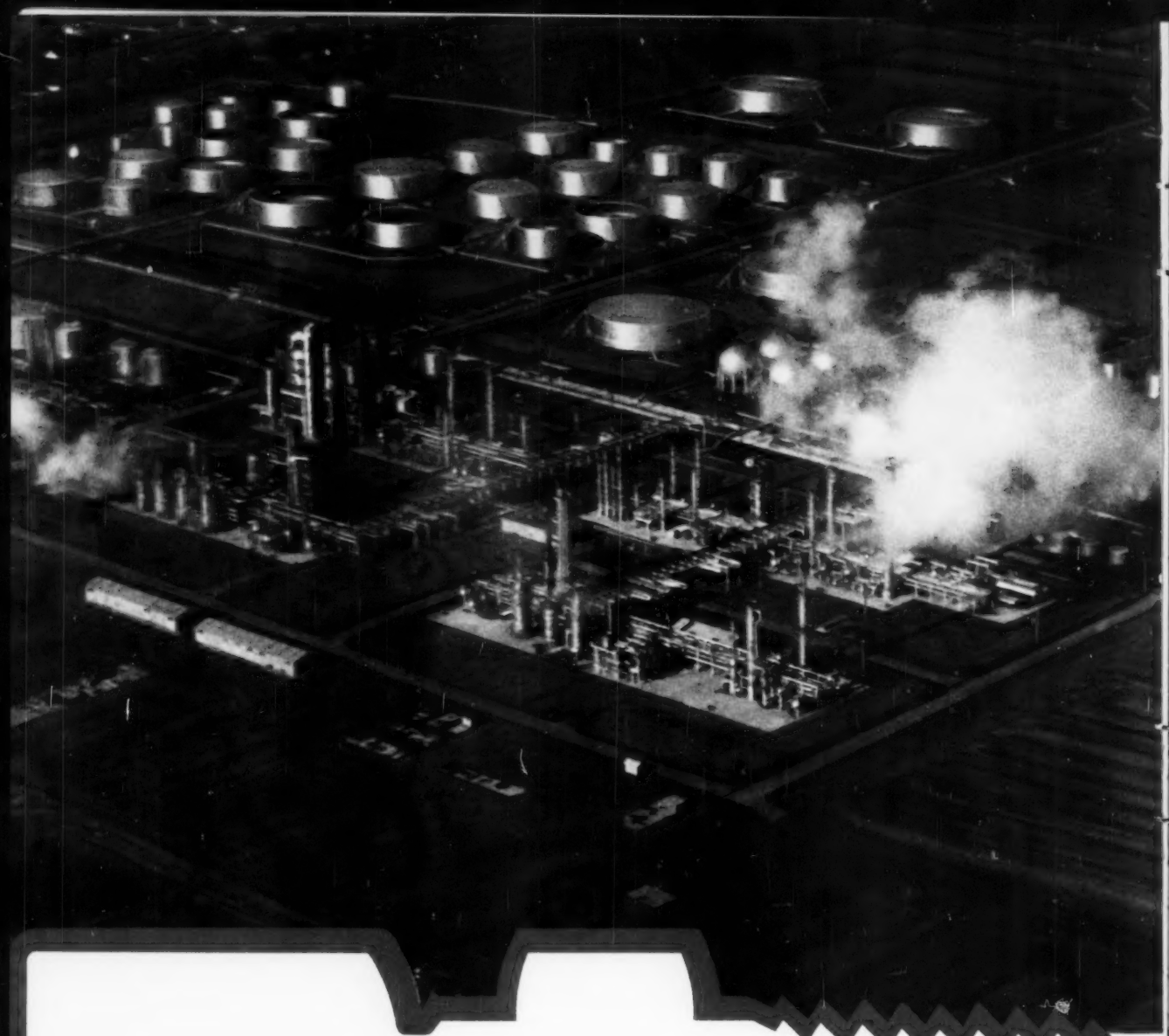

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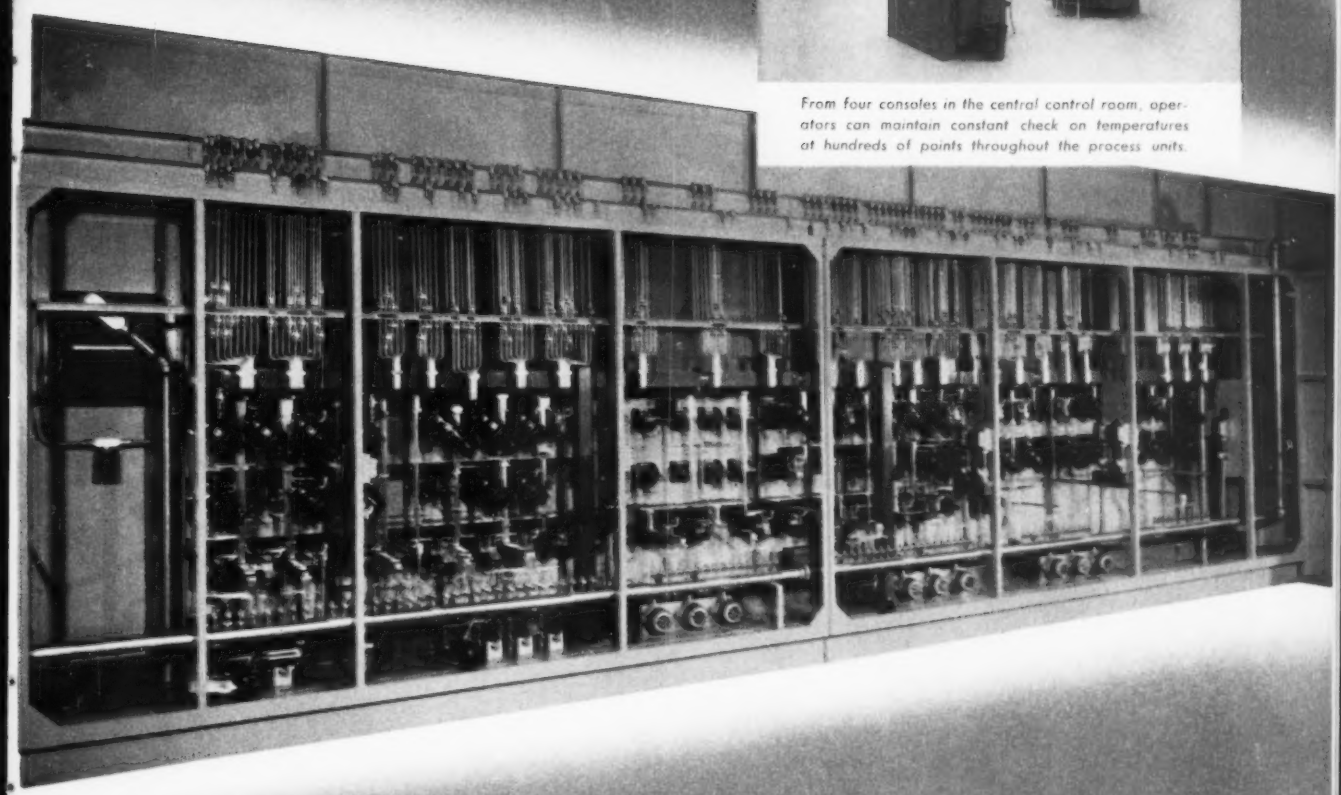
The capacity of this new Texaco Refinery at Anacortes, Washington, is 45,000 barrels of crude oil per day, processed into a full range of finished Texaco quality products . . . high octane and regular gasoline, jet fuel, burner oil, kerosene, diesel oil, bunker fuel and propane gas.

Quality control is the watchword here . . . with automation and instrumentation bearing the major responsibility. More than 30,000 Swagelok Tube Fittings were used for instrumentation and steam tracer lines throughout the plant, including over 12,000 for the panel boards in the control center. In keeping with their high standards of quality in panelboard manufacturing, Swanson Engineering & Manufacturing Co. selected Swagelok Tube Fittings to secure precision control with torque-free seals that are absolutely tight. In the science of sealing, Swagelok Tube Fittings approach the ultimate desired by designers today.

CREDITS: *Owner: Texas Company. Complete engineering procurement and construction: Bechtel Corporation, San Francisco, Calif. Panel Boards for Central Control Room manufactured by Swanson Engineering & Manufacturing Co., Inglewood, Calif.*

From four consoles in the central control room, operators can maintain constant check on temperatures at hundreds of points throughout the process units.



This view of back of panel board illustrates the outstanding craftsmanship in design and construction by SWANSON ENGINEERING & MANUFACTURING CO.

In this great new Texaco Refinery Swagelok Tube Fittings stand guard against pressure, vibration and torque

In the refining of 45,000 barrels of crude per day at the new Texaco Refinery, obviously all of the units in the process control line must bear a big load of trust in performance.

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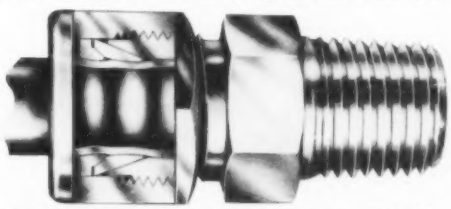

Swagelok Tube Fittings are available in any machinable metal or plastic, in sizes for 1/16" through 1" O.D. tubing.

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This offshore rig stands in the

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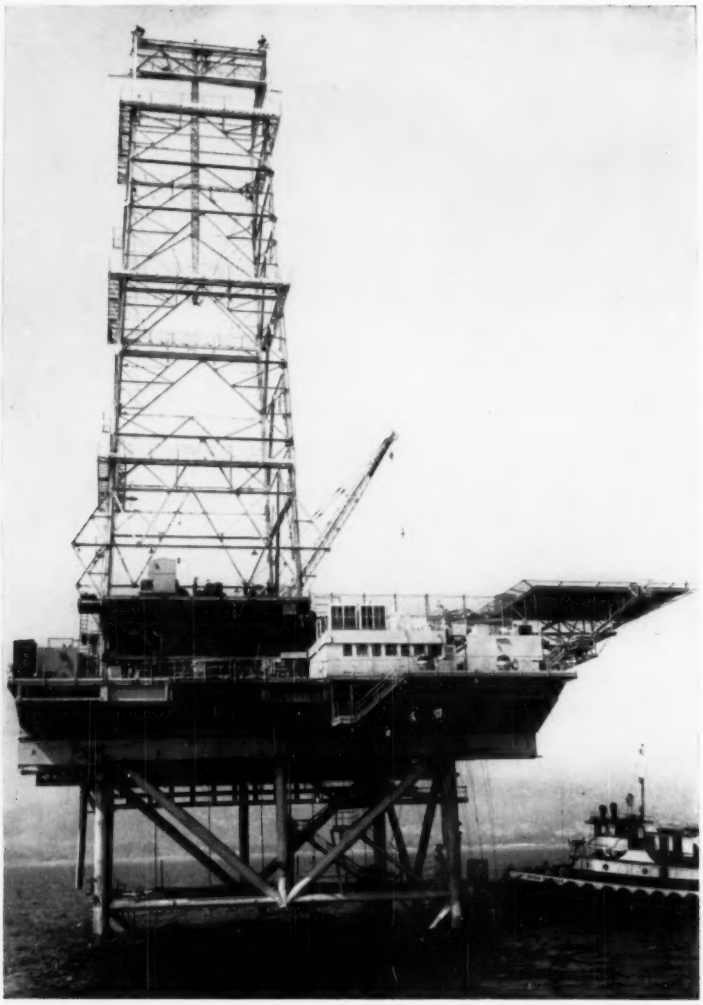

Standard Oil Company of California, operator of Standard-Humble Summerland State No. 1, uses proven Amercoat protective coatings to prolong the life of its new offshore rig off Santa Barbara. You will find them on all surfaces above elevation 8'10" MLLW, including the movable fender, boat landing, walking surfaces, gratings, hand rails, stair treads, ladders, ladder cages, water tanks.

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For detailed information, technical data and assistance with your marine corrosion problems, write to any of the Amercoat offices listed below:

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South Gate, California

- **921 Pitner Avenue, Evanston, Illinois**
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- **360 Carnegie Avenue, Kenilworth, New Jersey**
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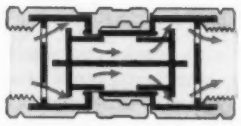

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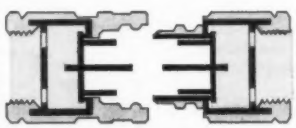

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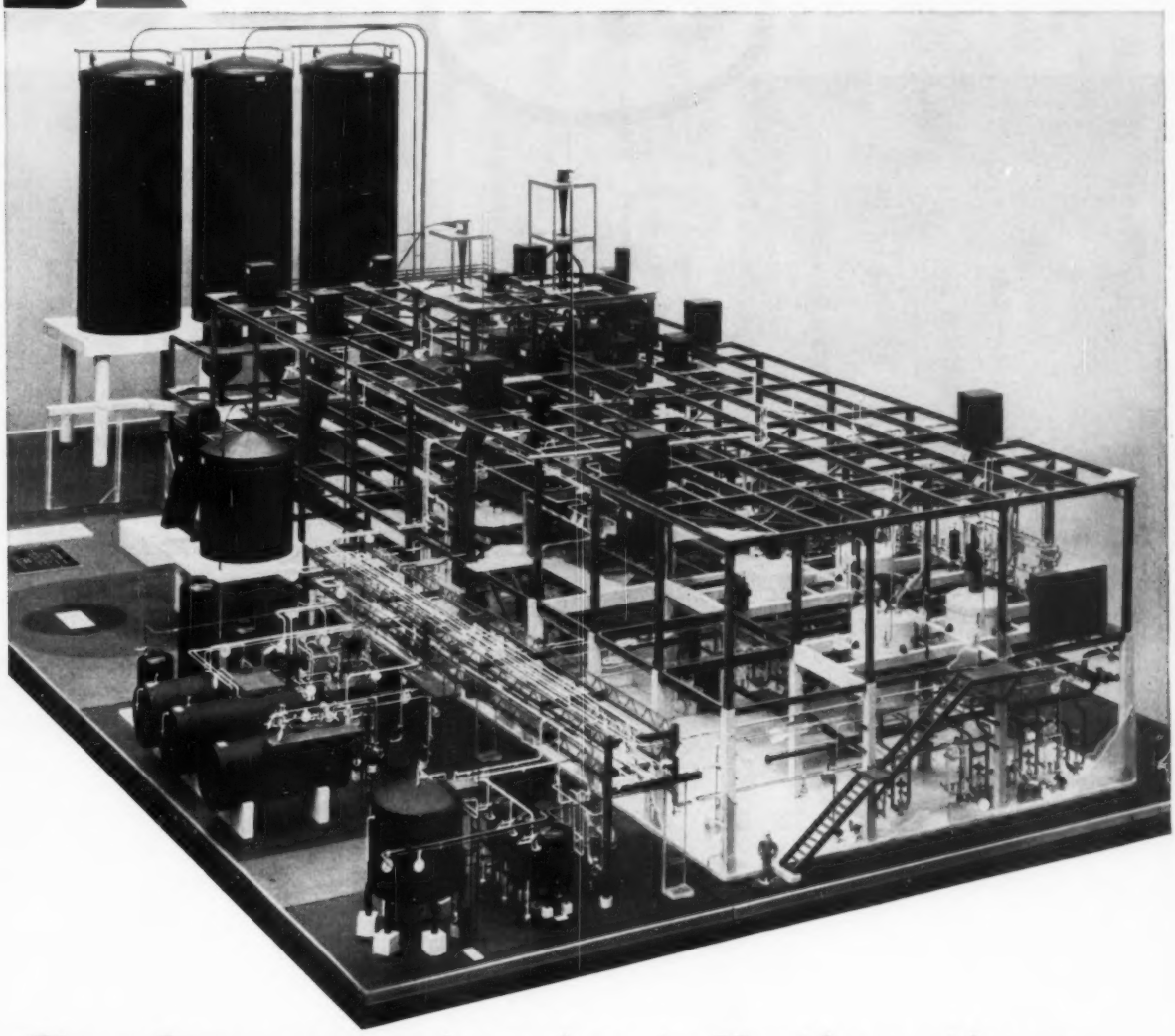
Blaw-Knox designs and builds Cosden's polystyrene plant. Builder of over 90 plastics and resins plants, Blaw-Knox is a leading contractor for this industry's most progressive projects.



Cosden cut pipe installation time by two months with this model

Compared with equivalent projects using conventional design-construction methods, Blaw-Knox's unique model approach builds a plant faster, and at lower cost.

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plant builders for industry . . . BLAW-KNOX

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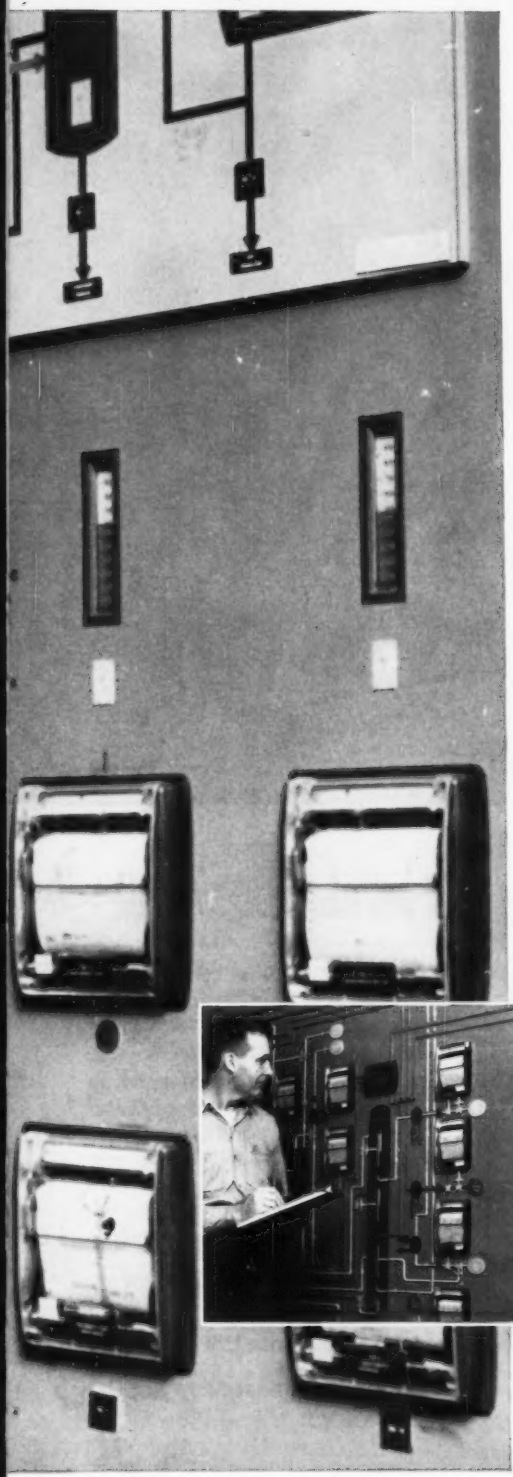
Esso looks to

Consotrol Control panel for Powerformer* at Esso's Bayway Refinery, Linden, New Jersey. Complete Consotrol Control Station slides out from front of panel as a unit — makes servicing easier for Esso technicians.

*Trade mark, Esso Standard Oil Company

Consotrol* instruments

for dependable control at their Bayway Refinery



Precise, dependable, centralized control . . . full-scale, easy-to-read chart records . . . simplified maintenance from the front of the panel. No wonder leading refineries like Esso specify Foxboro pneumatic Consotrol instrumentation.

Consotrol control stations are so compact, four can fit where one circular chart instrument used to go. Yet recorders still have a full-scale, 4-inch chart — can furnish continuous recording of up to 3 different variables on the same chart.

Consotrol M/58 Controllers handle a full-range of control functions: auto-selector . . . cascade and ratio systems . . . automatic batch control.

Get the complete story on pneumatic Consotrol instrumentation by writing for Bulletin 13-18. **The Foxboro Company, 746 Neponset Ave., Foxboro, Mass.**

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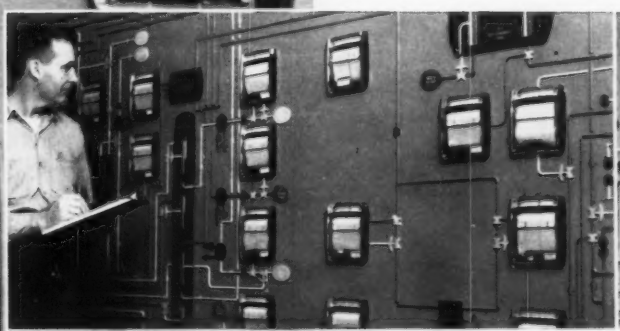

▲ Foxboro control panel for #6 Pipe Still was installed in 1952. Consotrol recorders have a full-scale 4" chart which travels vertically. Pen arm moves in an arc — eliminates extra linkage common to instruments that must convert rotary motion to straight-line pen travel.

▲ This hydrofiner full-graphic panel was designed and built by Foxboro in 1954. Panel includes 54 Consotrol Recorders, 44 Controllers. Ethylene Plant control panel (not shown) includes another 100 Foxboro pneumatic Consotrol instruments.

FOXBORO

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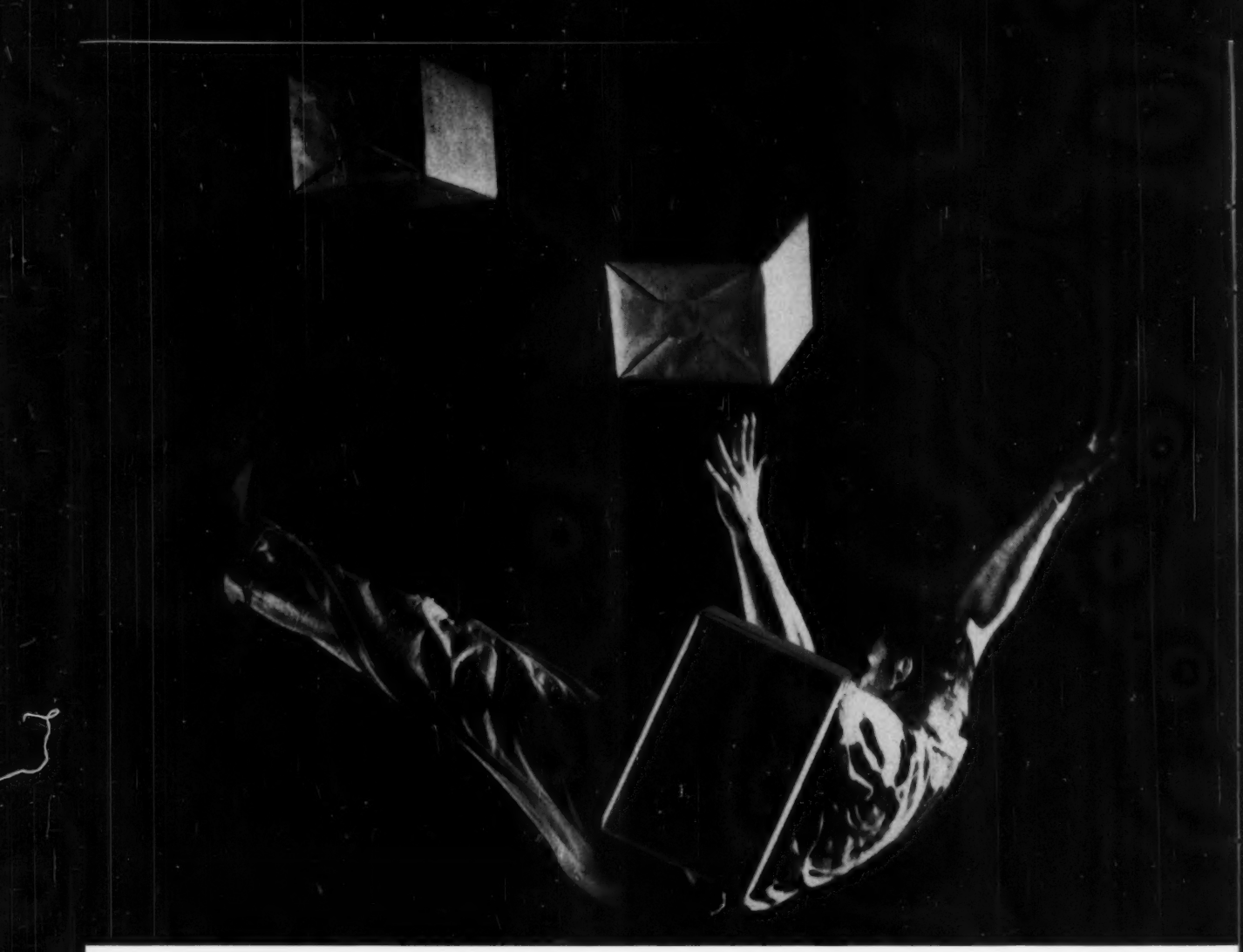
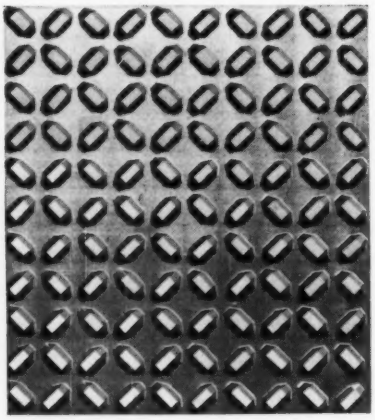


One slip can cost more than USS Multigrip

$100,000 for a single fall? Sounds fantastic, doesn't it? But there are actual cases involving suits for $100,000 or more for single falls. The average cost of injuries from slips and falls is lower than that, of course. In six states, during 1954, the cost per fall averaged close to $900.

You can eliminate many slips and falls by giving your workers a floor studded with cleats—USS Multigrip. This floor plate provides safe traction in any direction. The cleats are flat on top, easy to walk on—and do not catch the shoe.



For machine shops, loading platforms, cat-walks, and other dangerous locations, Multigrip supplies safety plus.

Where floors take a heavy beating from traffic, Multigrip will stand up for years under constant use. Oil and water won't soak in and can be easily removed from the surface with regular cleaning materials. You save money by having a floor that is easy to sweep or flush clean—and there's little or no maintenance.

On your next inspection trip, search out the danger spots—and make them safe with USS Multigrip.

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The Mail Box . . .

Catches Error

To The Editor,

I should like to draw attention to two errors in my article, *"Use Enthalpy for Two-Phase Δ P,"* which appeared in PETROLEUM REFINER, January 1959, page 217.

First, the numerical factors 0.811 and 0.258 in Equation (30) refer to the use of consistent units (i.e., all variables expressed in ft-lb-sec system units or cm-gm-sec system units) and *not* to the use of conventional units as I have stated. If the variables are expressed in conventional units listed below Equation (30), the numerical factors become 2.85×10^{-7}, and 1.3×10^{-5} respectively, and equation (30) then reads:

$$2.85 \times 10^{-7} \frac{W^2}{D^4}\left(\frac{\partial V}{\partial P}\right)^{\circ}_{T} + 1.3 \times 10^{-5} \frac{W^3}{D^6 Q} F V_o f \left(\frac{\partial H}{\partial P}\right)^{\circ}_{T} = -1$$

The same considerations apply to Equation (34).

Secondly, the friction factor f, as defined by Equation 1 in my article will be four times as large as when it is defined by the conventional alternative equation which gives the form:

$$dp = -\frac{2W^2V}{DA^2} f c dH - \frac{W^2}{2A^2} dV$$

Thus for the first trial calculations f should be taken as being 0.016, *not* 0.004 as stated. In view of these alternative defining equations for f, care should be taken when obtaining values of f from the published data, to ascertain on which basis they have been derived. Thus values of f derived from Lockhart & Martinelli's correlations should be multiplied by 4 before substitution into equations (30) and (34).

(Apologies for my having allowed these errors to escape my notice in the first place and for letting them go uncorrected for so long.)

A. Doll-Steinberg

London, England

The Editors of Petroleum Refiner invite letters from readers discussing topics pertinent to the industry

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with Quaker Petroflo tank-truck hose

You can run fuel oil, gasoline, processing oils, and many other petroleum products through Quaker Petroflo Hose. Its Buna-N tube resists a wider range of attack than neoprene-type tubes do. It'll take a beating!

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Citric Acid -- Dowell's New Service for Cleaning Stainless Steel Process Equipment

Now, for the first time, plant operators can be sure of a new degree of safety in the cleaning of their pressure units containing austenitic stainless steel—for example, heat exchangers, stainless-clad pressure vessels, atomic reactors, and supercritical-pressure steam generators. Citric Acid service by Dowell provides a new, effective method for these special chemical cleaning situations.

The Citric Acid used in Dowell chemical cleaning is inhibited with an *exclusive chloride-free* inhibitor. Cleaning with this new field-proven solution assures a chloride-free solvent system, and thus helps prevent chloride stress-corrosion cracking.

Dowell Citric Acid also provides other significant advantages: Citric Acid stabilizes dissolved iron and helps prevent precipitation of insoluble iron compounds when neutralizing chemicals are used. Flushing of the unit is not as difficult when Citric Acid is used. Citric Acid is especially suitable where stainless steel and other metals are used together in construction of the unit.

Citric Acid cleaning with a chloride-free inhibitor is just one of the new ideas from Dowell research. Other recent contributions include the new "white glove" standards of cleanness, copper removal agents and the new jetting device for cleaning heat exchanger tube bundles.

Ask your Dowell representative about Citric Acid service and Dowell chemical cleaning programs for your plant equipment. Dowell, the leader in chemical cleaning service and research, operates in every major industrial area through 165 offices and stations. Dowell, Tulsa 1, Oklahoma.

Chemical cleaning service for all industry

DOWELL

DIVISION OF THE DOW CHEMICAL COMPANY

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THE 1959 API . . . AND WORLD PETROLEUM CONGRESS MEETINGS

Two meetings of high technical importance to refiners this year were the American Petroleum Institute Division of Refining mid-year meeting and the Fifth World Petroleum Congress. The API meeting in late May immediately preceded the Congress, May 30-June 5.

Special emphasis at the API was given to process improvements with three sessions scheduled. Other sessions featured were centrifugal pumps, corrosion, instruments, training, safety, petroleum products, electric power, fundamental and analytical research.

The World Petroleum Congress included the announcements of several new processes—refining and petrochemical. PR editors have chosen the following API and WPC papers for your special attention.

API MEETING

Aluminizing Resists Refinery Corrosion 153

Extraction Goes After High Octanes . . 161

Alky Units Revamped for More Output . 165

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CORROSION

Aluminizing Resists Refinery Corrosion

Aluminizing carbon steel or low alloy steel is a relatively inexpensive method of protecting against refinery sulfidation and oxidation

C. F. Tisinai and C. H. Samans
Standard Oil Company (Indiana), Whiting, Ind.

SEVERE SULFIDE corrosion by hydrocarbon atmospheres containing hydrogen sulfide-hydrogen mixtures was first encountered in reforming units.[1] It was also observed in preliminary work on hydrogenation units.[2]

Under refinery conditions, the basic corrosion reaction is:

$$Fe + H_2S \rightleftarrows FeS + H_2$$

Because the reaction is reversible, the specific hydrogen sulfide and hydrogen concentrations will determine the rate of corrosion. In fact, at any temperature, there is a specific hydrogen sulfide:hydrogen ratio above which corrosion occurs and below which corrosion does not occur. This relationship, which has been determined by T. Rosenqvist,[3] is known as the thermodynamic cutoff. A. Dravnieks and C. H. Samans[4] have given the rates of corrosion above the thermodynamic cutoff as a series of iso-corrosion curves relating corrosion rate, temperature, and hydrogen sulfide:hydrogen ratio. In the absence of oxygen, which can alter these corrosion rates significantly, corrosion at a pressure of 300 psia should be approximately 3 to 4

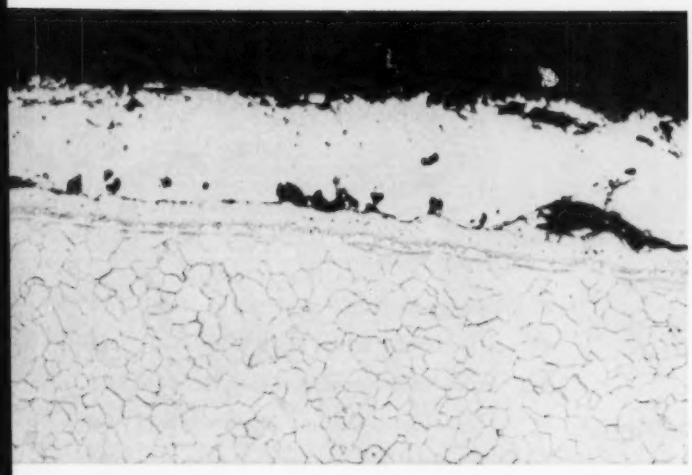


FIGURE 1—Typical section through calorized carbon-steel tube. Note nearly complete removal of carbon from steel base metal (150X).

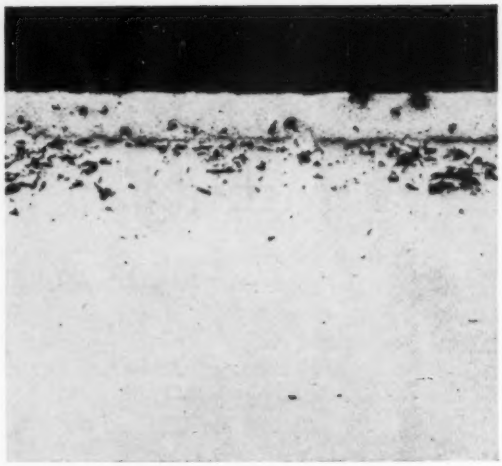


FIGURE 2—Typical section through aluminum dipped carbon steel (150X).

times as great as at atmospheric pressure. The data also indicate that sulfide corrosion under these conditions can be controlled by desulfurizing the feed to a low enough level. A sulfur level suitable for reformer operation is readily attainable. However, sulfidic corrosion in reforming also can be controlled by the use of aluminum coatings. This method is appreciably less expensive than the use of austenitic stainless steels.

Similarly, sulfide corrosion can occur in other units such as cokers and pipe stills. As-sprayed aluminum coatings have been used to overcome this type of corrosion, but not always successfully. To improve the effectiveness of aluminum coatings, limited work has been done on diffusion heat treatment of such sprayed equipment in the field.

Early aluminizing of refinery equipment was confined almost entirely to the well-known calorizing process and to the, at that time, lesser known aluminum-dipping process. Aluminum coatings had been sprayed on a few vessels in an effort to secure increased corrosion resistance, but these attempts had met with varying success largely because of unreliable adherence. Many refiners disliked calorized parts because the protective layer was relatively thick, quite brittle, and often tended to spall. On the other hand, numerous valves and fittings coated by dipping were quite successful, although in a few large parts, in which uniform heating rates could not be maintained, distortion caused some problems.

For dipped coatings, several different procedures are used, some of which are patented. In a typical procedure, the parts are preheated in the presence of a molten flux and then dipped into a molten bath of aluminum whose impurity content is controlled to a limited extent. A diffusion bond of a brittle aluminum-iron compound is forced between the ferrous base metal and the aluminum surface layer. Control of the time and temperature of dipping readily controls the thickness of this bond layer on small parts; however, with large parts, which inherently will have a high heat content, proper control may be a problem. It is considered desirable to keep the bond layer as thin as possible because, as the bond layer thickens, its tendency to crack and spall under some conditions increases. The resistance of both the aluminum left on the surface and the alloy bond layer to sulfidic corrosion is quite satisfactory. The cost of dip coating usually is determined by the weight of the part being dipped. Thus, for heavy valves and fittings (headers weighing as much as 1,800 pounds have been used in some refineries), this cost often is high, even though the actual surface which must be coated may be of relatively limited extent. In addition, because the baths available are not large enough to take care of tubes or lines of any appreciable length, the dip method is not well suited to the internal coating of furnace tubes and transfer lines. Such lines frequently are sources of scale formation, even though their actual corrosion rates may not be too high. Even the alternative of dipping the tubes from each end has not been very attractive because tube length still is restricted to approximately 15 to 20 feet. Also, it is difficult to obtain a clean, dross-free, completely coated internal surface consistently on even a relatively large-diameter tube.

A few companies which spray metals have become interested in the technique of spraying tubes internally. However, even though various methods of surface preparation or undercoating may be used to increase adherence, the basic adherence of an as-sprayed coating still is entirely mechanical. Therefore, to increase the adherence of these sprayed coatings, they are heat-treated at temperatures approximately 50 F. to 100 F. above the melting point of aluminum to develop an aluminum-iron alloy bond. Studies have been made on various methods of treating tubes after spraying, on spraying tubes externally to increase oxidation resistance, and on spraying refinery vessels internally to secure increased corrosion resistance.

Typical sections through coatings made by calorizing and by aluminum dipping are shown in Figure 1 and Figure 2, respectively. A section through a typical sprayed and heat-diffused aluminum coating is shown in Figure 4.

Use of As-Sprayed Coatings. The technique of spraying aluminum on steel surfaces requires careful surface preparation to obtain a good mechanical adherence of the aluminum to the steel. Although much experience has now been obtained by some spraying companies, there are newcomers who are spraying coatings for these particular applications who may not be completely aware of all of the precautions required. Even if a very adherent aluminum is placed on steel in the shop, this coating is subject to damage if proper handling precautions are not observed during shipment. Detailed engineering standards are desirable to govern the surface preparation, aluminum wire quality, procedure of metallizing, post-metallizing sealing, and diffusion heat treatment.

In 1953, for example, four converters for an acid contact plant were to be used in the as-sprayed condition. Two of the converters were mishandled during shipping and 16 details, including baffles and nozzles, showed definite flaking and gouging of the aluminum coating. An inspection of the other two converters at the fabricator's shop showed that 19 other details including baffles and clips showed definite flaking.

One of the first refinery applications of spray aluminizing was in carbon-steel coke drums of a pipe still, the aluminum coating being used in the as-sprayed condition. This unit was built in 1940 and was run without corrosion protection in the drums until 1944. Then all four drums were strip-lined with 11 to 13 percent chromium stainless steel. Within two years of service, some sections of the strip lining started to give trouble and, by 1954, required extensive repairs. (All service times given are unit hours onstream. The hours the drum operates would be on the order of half of this.) Therefore, portions of the liners were removed and spray aluminizing was used for repair in three of the drums. Approximately 300 square feet of surface was spray-aluminized in each of two drums and 530 square feet in a third drum.

Repairing as-sprayed coatings. The procedure used for repairs was as follows:

1. Heat the drums gradually to approximately 500 F. and hold for 6 hours to drive off oil vapors and moisture.
2. Sandblast and back-fill with weld metal all corroded areas deeper than ⅛ inch.
3. Gritblast all steel surfaces thoroughly with size G-16 steel grit.
4. Apply a flash coat of spray-metallized mild steel (to increase adherence) approximately 0.001 inch thick.
5. Spray on pure aluminum to the desired total thickness of 0.010 inch to 0.20 inch (5 to 7 coats as a rule, although in some regions thickness was not known too accurately).
6. Paint with two coats of silicone aluminum sealer, with a minimum drying time of 30 minutes between coats.

After 609 hours of service, inspection indicated that the aluminum had spalled off several areas; that it had worn thin (to approximately 0.002 inch or less) in other regions, particularly in the cone section where abrasion from the coke also was an important factor. The spalled or thinned areas were readily apparent because they were not covered with coke, whereas those areas that still were metallized were covered with a thin layer of coke which could be removed only by sandblasting. It is probable that the spalled regions, as well as those in which the bond was poor, had not been cleaned adequately before the aluminizing was applied. During this and subsequent inspections it was noted that a thin, dense layer of coke adhered well to the rougher aluminized surface. This undoubtedly helped in sealing the aluminum coating, thereby minimizing the penetration of liquids and vapors through it.

Thirteen months after the initial metallizing (after the unit had 7,350 hours of service), 804 square feet (59.7 percent) of the original metallized area had to be recoated and 254 square feet additional was aluminized (after the stainless strip liner was removed). This time, as a result of experience, more care was used in surface preparation before coating. The total area which had been metallized up to this period was approximately 1,600 square feet. An inspection 16 months later (after 6,288 hours of additional service) indicated that only 12 percent of this total area was not coated adequately, for one reason or another. However, this was an inspection shutdown only, and no repairs were made.

Approximately 19 months later (after 10,500 hours of additional service), 1,218 square feet of the previously metallized area had to be remetallized and 157 square feet additional was aluminized. Of the area previously coated, 376 square feet still was in satisfactory condition. No further metallizing work has been required since early in 1958.

The experience to date on these coke drums indicates that a service life of approximately 18 months for a spray-metallized and sealed aluminum coating is possible, provided surface preparation is adequate and clean conditions are maintained while the coating is being applied. Even though the bond is only mechanical in these coatings, it has been shown repeatedly that adherence can be good. In fact, on several occasions it was extremely difficult to remove the original coating by sand-or gritblasting before remetallizing. It must have definite limitations for applications such as this, particularly since a diffusion heat treatment is not used. If spalling occurs, corrosion could lead to thinning of the vessel wall in that region. Nevertheless, for this application, aluminizing appears to be the least expensive type of corrosion protection presently available.

Coating pressure stills. As-sprayed aluminum coatings also were placed on the internals of vessels of two continuous pressure stills. All the procedures used in aluminizing were similar, and all of the coatings failed in approximately the same manner. In one vessel the upper 15 feet including the top head, was sandblasted; heated briefly to 500 F. to 600 F. to remove oil; gritblasted; given a flash coat of mild steel; aluminum-sprayed to a thickness of 0.012 inch to 0.020 inch, then painted with a commercial silicone aluminum sealer. The unit had operated approximately 4.377 hours when it next was examined about

two years later. At this time the metallized area was gritblasted to remove the coke and any loose aluminum. Approximately 35 percent of the original metallizing had spalled in service or was removed by the gritblasting. In the 30-inch-wide area between the two top doughnut baffles all of the metallizing was removed by the blasting.

Apparently, in the deteriorated regions, oil vapors penetrated the pores of the coating and were converted into coke by thermal cracking. This eventually both opened up the aluminum coating internally and separated it from the steel. Ultimately, the separation became sufficient to allow the vapors to cause sulfidic corrosion of the steel shell in the 35 percent defective area. On the other hand, the intact metallized coating on the remaining 65 percent of the area appeared to have resisted the corrosive environment and to be as thick as it was when applied originally.

In another vessel, approximately 12 feet of the upper 15 feet of the vessel (8 feet above and 4 feet below a 5½-inch-thick shell-transition section) was aluminized. The entire aluminum coating was inspected visually after 1,664 hours of operation. It appeared to be intact and showed no evidence of coke adherence. After 5,590 hours of operation, 150 square feet of the coating was checked in a total of five locations. Measurements showed that the coating thickness ranged between 0.002 inch and 0.010 inch, but the coating still was intact although it had some coke deposit on its surface. After two years of service, the entire surface appeared to be covered by a coke deposit. At this time, the interior of the vessel was decoked mechanically and 20 percent of the aluminized surface was sandblasted, in addition, to remove traces of the coke. The sandblasted surfaces showed virtually no evidence of the aluminum coating. An examination of the remaining 80 percent of the aluminized area indicated that oil vapors had penetrated the pores of the coating and had been converted to coke by thermal cracking. The deposited coke completely separated the aluminum coating from the steel. Thus, for this application, an as-sprayed aluminum coating was not completely satisfactory.

Use of Sprayed, Heat-Diffused Aluminum Coatings. An aluminum-sprayed and heat-diffused tube, a calorized tube, and a Type 304 stainless tube were placed on test in a reheat furnace of a regenerative platinum catalyst reformer. The rest of the tubes in this furnace, 8 inches O.D. by 0.400 inch minimum wall, were of 2¼ percent chromium-1 percent molybdenum alloy. At the last inspection, these tubes had been in service for 17,620 hours — 8,398 hours without desulfurization of feed stock (uncoated tubes corroded at a rate of 0.040 inch per year), and 9,222 hours with desulfurization of feedstock (uncoated tubes corroded at a rate of 0.010 to 0.020 inch per year). At this time, the Type 304 stainless-steel tube was not affected. The calorized tube showed no evidence of either corrosion or spalling. The aluminum-dipped tube (dipped from each end, leaving the coated areas with considerable dross and an uncoated, 8-foot-long center area which corroded at the normal rate) was in good condition, with the dross still visible, except for a few small areas adjacent to welds where the aluminum coating had spalled. The aluminum-sprayed and heat-diffused tube had not corroded, and its aluminum coating still was intact except for a few spalled areas near the weld. On the inside surface of each of these four tubes there was a thin, dull-black surface deposit of unknown nature.

Several pieces of equipment on the desulfurizer which was added to this unit also were aluminum-sprayed and heat-diffused. The channel surfaces of two reboilers showed only slight spalling of the coating (where a 1-inch nozzle was welded into the exchanger nozzle) after 5,844 hours of service. In like manner, the channel surfaces of a prefractionator feed-desulfurizer furnace feed exchanger showed no evidence of corrosion or spalling after 9,200 hours of service. Various other aluminized lines were also in excellent condition after 9,200 hours of service.

In the preheat and the three reheat furnaces of another regenerative platinum catalyst reformer 128 spray-aluminized and heat-diffused tubes, 6-inch O.D. by 0.3125 inch minimum wall and 2¼ percent chromium-1 percent molybdenum alloy, were used. This was the first major installation of spray-aluminized, heat-diffused tubes; and conditions were far from ideal during the cleaning, aluminum spraying, and diffusion heat treatment stages of the coating process. Nevertheless, visual inspection of the tubes after 15,728 hours of service revealed only

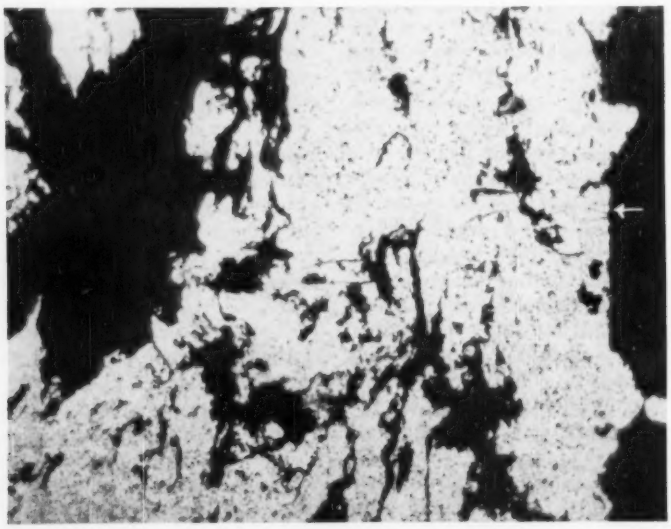


FIGURE 3—Mechanical decoking caused fissuring and removal of aluminum layer on this as-sprayed, heat-diffused coating from a furnace tube. Arrow shows particles of the iron-aluminum alloy (500X).

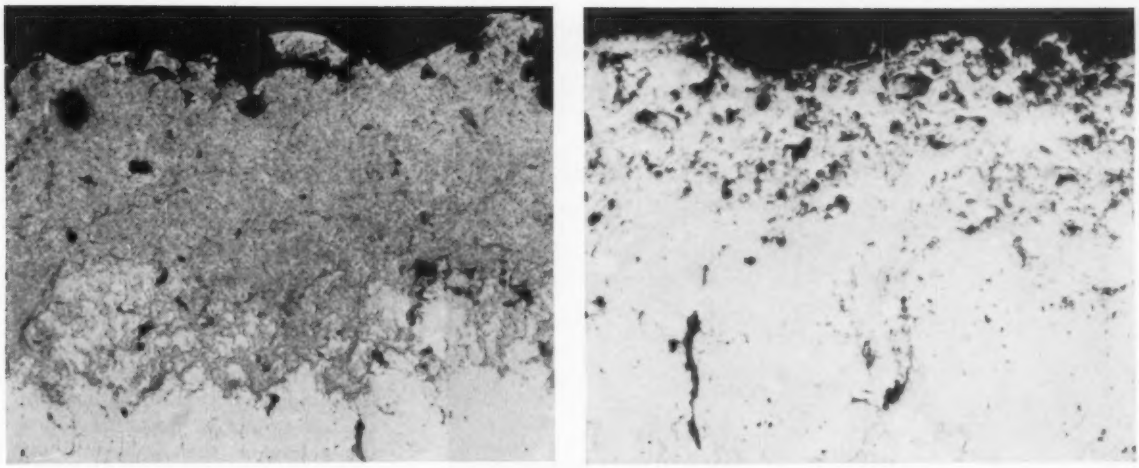


FIGURE 4—Photo at left shows sprayed aluminum coating diffused for 15 minutes at 1,300 F. Photo at right illustrates appearance after an additional two hours of heating at 1,300 F. Note how alloy bond layer has increased in thicknesss and the free aluminum layer at top surface has decreased in thickness (100X).

two small spalled areas, both of which had been noted soon after installation and neither of which had grown significantly since. Test coupons which did not have an aluminized surface showed corrosion rates on the order of 0.013 to 0.023 inch per year, depending upon the location.

Carbon-steel tubes, 5 9/16-inch O.D. by 0.258 inch minimum wall, in a reformer desulfurizer furnace at another refinery were corroding at a rate as high as 0.086 inch per year. Therefore, in August 1956, 40 of the lower row radiant roof and wall tubes were replaced with 5 percent chromium-½ percent molybdenum tubes, 5½-inch O.D. by ⅜ inch average wall approximately 40 to 44 feet long, which had been pickled, spray-aluminized, and heat-diffused. In November 1956, after 1,679 hours of service, the tubes were turbined with the use of dull tools to remove coke; in August 1957, after a total of 7,416 hours of service, they were again turbined.

At this time, several large and many small pieces of the aluminum layer were noticed in the dislodged coke, and visual examination indicated that 80 to 90 percent of the aluminum coating (as judged by color alone) had been removed. One of the larger pieces of removed aluminum was examined thoroughly. Chemical analysis showed it to have 84 percent of aluminum, 1 percent of ferricoxide, and 15 percent of hydrocarbon residue. Figure 3 shows the severe fissuring and deformation of the aluminum coating caused by mechanical decoking, as well as some aluminum-iron alloy particles which were produced by the diffusion heat treatment. The appearance of the removed aluminum layer, if this piece was typical, indicates that turbining removed little more than the residual aluminum layer and that substantially all of the aluminum-iron alloy bond layer probably remained on the surface. After an additional 7,114 hours of service, an inspection revealed that very little corrosion had occurred. This lack of corrosion is attributed to the protection offered by the aluminum-iron alloy bond layer which had not been removed by the turbining.

Two externally aluminized and heat-diffused 5 percent chromium-½ percent molybdenum tubes were installed in the lower roof section of each of the two furnaces in the delayed coking section of a pipe still. Previously, these roof tubes had to be replaced in as short a time as 18 months to two years because of excessive oxidation. After 3,350 hours (September 1958) of operation the aluminum coatings were found to be in relatively good condition. There were a few localized areas of spalling on the underside of the tubes, but this was considered to be unimportant because the coatings had been diffused. Small bright and shining droplets or globules of aluminum also were found to be hanging from the bottom of the tubes. This indicates that some of the aluminum had melted, probably during a recent onstream decoking operation. Although these results look promising, service experience still is insufficient to determine whether or not the oxidation resistance of the aluminized tubes will be better than that of the plain 5 percent chromium-½ percent molybdenum tubes.

Experimental Studies of Sprayed Aluminum Coatings. Since the feasibility of the diffusion heat treatment of sprayed aluminum coatings on the inside and/or the outside of furnace tubes had been demonstrated, an additional test was made by a commercial fabricator to determine if the diffusion heat treatment of a spray-aluminized pressure vessel could be given as a field stress-relief heat treatment. For this purpose, a 3/16-inch thick carbon-steel test vessel, approximately 30 inches in diameter and 5 feet long, was sprayed with 0.020 inch of aluminum. This coating was sealed with a hydrolyzed ethyl silicate solution, shot-peened, and subjected to a simulated field stress-relieving heat treatment. The outside of the vessel was insulated; the vessel was heated to 1,300 F. for 15 minutes by flue gases from a portable combustion unit, and then air-cooled. A sample was removed for metallographic examination. The vessel then was reheated to 1,300 F. for an additional 2 hours, it was air-cooled, and another sample was removed. During these heat treatments the oxygen content of the flue gases was kept below 2 percent. (Attention is called to United States Patent No. 2,845,-

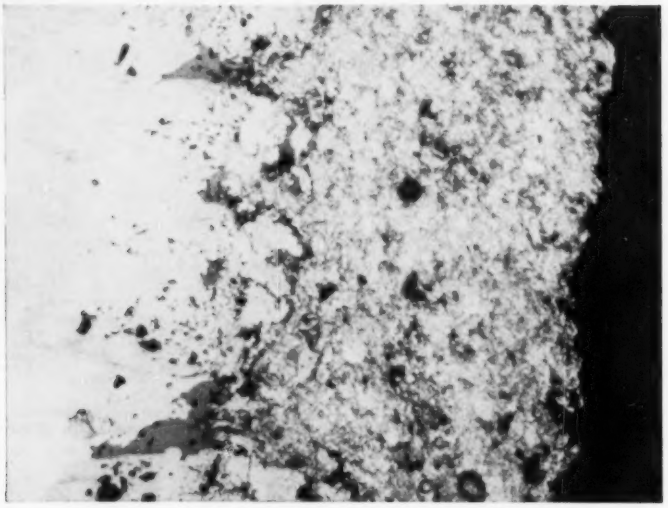


FIGURE 5—This aluminized coating was held for 96 days in a furnace which was maintained at approximately 1,300 F. A good portion of the heavy aluminum coating is still present (100X).

366, "Coating Articles with Metal," issued to Albert W. Schroeder on July 29, 1958.) Figure 4 shows the structures of the coating after heating for 15 minutes and for 2 hours additional. The longer treatment increased the thickness of the alloy bond layer from 0.004 inch to 0.010 inch and decreased the thickness of the unalloyed residual aluminum coating from 0.013 inch to 0.006 inch. This test indicates the feasibility of using heat-diffused, sprayed aluminum coatings for protecting pressure vessels, provided the initial aluminum coating is deposited properly on a clean surface, the temperature of the diffusion heat treatment (and stress relief) is approximately 1,300 F., and a protective atmosphere is maintained during the heat treatment.

The same fabricator reported that he had been able to aluminize the internals of a 36-inch valve, which had some zones in which the metal thickness was as much as 7 inches, and then to obtain an excellent iron-aluminum alloy bond, with no aluminum draining, by a subsequent diffusion heat treatment. During this heat treatment, the sprayed surface of the valve was protected by oil-pumped nitrogen. The coating also had been sealed with hydrolyzed ethyl silicate prior to the diffusion heat treatment.

Further Studies of Aluminum Coatings. It has been found by laboratory studies that the unalloyed dipped aluminum coatings readily are lost from the metal surface by alloying with the steel base at temperatures below the melting temperature of aluminum. On some steels, such as Type 405 (11 to 13 percent chromium-aluminum) stainless, the aluminum "disappears" relatively rapid. It also was found that, regardless of the type of steel, if aluminum-dipped steels are held at temperatures more than approximately 50 F. above the melting point of aluminum, the aluminum will disappear from the surface completely in less than 1 hour.

Spray-aluminized plate which was sealed with a hydrolyzed ethyl silicate solution and that heat-diffused in air for approximately 1 hour at 1,300 F. (aluminum layer 0.012 inch thick, alloy bond layer 0.006 inch thick) was heated at 950 F., 1,050 F., and 1,150 F. for times up to 1,024 hours without any significant change occurring in the thickness of either the aluminum layer or the alloy bond layer. However, when the spray-aluminized and diffused plate was held at 1,300 F. for times up to 16 hours the residual aluminum layer decreased in thickness until substantially no free aluminum remained. At the same time the alloy bond layer increased in thickness until it reached approximately 0.020 inch. Thereafter, it remained substantially unchanged in thickness even though the coated steel was held at 1,300 F. for 56 hours. Thus the rate of disappearance of the residual sprayed aluminum coating was slower than was observed for dipped aluminum coatings. Thickness measurements of the unalloyed aluminum, of the aluminum-iron alloy bond layer, and of the steel have indicated that the growth of the alloy bond is much faster into the aluminum than it is into the steel. This indicates that iron is diffusing more rapidly into the free aluminum layer than aluminum is diffusing into the iron base.

If a non-sealed (with no hydrolyzed ethyl silicate sealer, for example), sprayed-diffused coating is held at 1,300 F. in a vacuum or a gas with a very low oxygen content, the coating will drain from the steel surface very rapidly. However, if the coating is sealed (with hydrolyzed ethyl silicate sealer, for example), then the aluminum will not drain from the surface. Similarly, a non-sealed aluminum coating held in a protective atmosphere which still has some oxidizing potential will not drain from the surface. Similar tests conducted in the laboratory and by a commercial fabricator showed that when either group held an as-sprayed aluminized steel in hydrogen at 1,300 F., the aluminum drained from the surface. In like manner, when an as-sprayed aluminized steel was held in the laboratory at 1,300 F. in prepurified nitrogen (oxygen content below 0.001 percent and, theoretically, completely dry), the aluminum drained from the surface. However, when the commercial fabricator held an as-sprayed aluminized steel in oil-pumped nitrogen (oxygen content below 0.5 percent, and moisture content approximately 0.03 percent) at 1,300 F., the aluminum did not drain from the surface.

It appears, therefore, that sprayed and heat-diffused aluminum coatings will have considerable stability in the usual operating temperature range of refinery equipment. Even when the coatings are overheated slightly above the melting point of aluminum, there is an excellent like-

lihood that the worst result will be a surface composed of a layer of aluminum-iron alloy.

If the aluminum coating is thick enough, a certain portion may not become alloyed even with relatively severe temperature treatment. This is shown strikingly by another experimental test. The outer surface of a carbon-steel tube, 5-inch O.D. by ¼ inch wall, was spray-aluminized to a depth of approximately 0.030 inch over one-half of its length, sealed with hydrolyzed ethyl silicate, and thrown into a furnace used for stress-relieving heat treatments on a production basis. During four months in the furance, the tube was exposed to temperatures above 1,300 F. for at least 96 days. The uncoated portion of the steel scaled very badly, whereas the aluminized coated section remained in good condition. Also, it appears that with such heavy coatings, a virtual limiting of the thickness of the alloy bond layer occurs and the remaining aluminum remains substantially unaffected. Figure 5 shows that this exposure did not cause any significant damage either to the outer aluminum layer or to the alloy bond layer.

Fatigue tests on aluminum-dipped specimens of carbon steel and AISI stainless steels Type 410 and Type 304 (along with blanks of undipped materials) indicated that the presence of the iron-aluminum alloy layer reduced the fatigue strength of the carbon steel and of the Type 410 steel approximately 10 to 15 percent, but it did not significantly affect the fatigue strength of the Type 304 steel.

The nature of the surface of a sprayed and heat-diffused aluminum coating on steel may be determined by a spot test. A drop from a solution containing 3 g of potassium ferricyanide, 2 ml of concentrated nitric acid, and 98 ml of water, placed on the coating, will not change color if the material is essentially pure aluminum; will become blue immediately if the surface is base steel; or will assume a gradual blue spottiness if the surface is the iron-aluminum alloy.

Welding Problems on Aluminized Parts. There are some questions concerning the properties of welds made on aluminum-coated parts. To check the physical properties and soundness of welds of aluminized steels, a test butt weld was made between a 6-inch aluminum-dipped elbow and an untreated, 6-inch aluminum-sprayed pipe, both 5/16 inch thick. Both parent metals and the electrode were 2¼ percent chromium-1 percent molybdenum steels. On both parent metals, the aluminum coating extended to the edges of the machined surfaces. The weld was made in a horizontally fixed position with a 600 F. preheat and was allowed to cool slowly, wrapped in asbestos, after welding. The weldment was held at 1,300 F. for one hour and a furnace-cooled to stress-relieve the weldment and diffusion-bond the sprayed aluminum. The weldment then was grit-blasted to remove the spatter. In tensile tests of a flat, reduced-section specimen the fracture occurred outside of the weld at a stress of 71,000 psi; the yield strength was 47,000 psi, and the elongation 27 percent in 2 inches. A side bend test specimen bent 180 degrees satisfactorily. Metallographic examination showed that for at least ½ inch on either side of the weld in both the aluminum-dipped and the aluminum-sprayed materials no free aluminum was present, although there was some slight amount of scattered aluminum-iron alloy in this area. It was not known whether this aluminum (and most of the aluminum-iron alloy) was lost during welding or during gritblasting, although the former was suspected. The weld metal was quite clean, and no inclusions were found which could be attributed to possible contamination by the aluminum coatings. A chemical analysis of metal cut from the root pass showed that it contained 0.13 percent of aluminum. This amount of aluminum probably would be ineffective in controlling corrosion by gases containing hydrogen sulfide.

In another test, two samples of carbon-steel piping which had been spray-aluminized internally and heat-diffused were welded together with 1¼ percent chromium-½ percent molybdenum electrodes by a fabricator who claimed that the technique employed caused sufficient aluminum to be retained in the root pass to afford it reasonable resistance to attack by gases containing hydrogen sulfide. One weld was made with the use of a silicone flux backup; after welding, the only internal area which did not have an

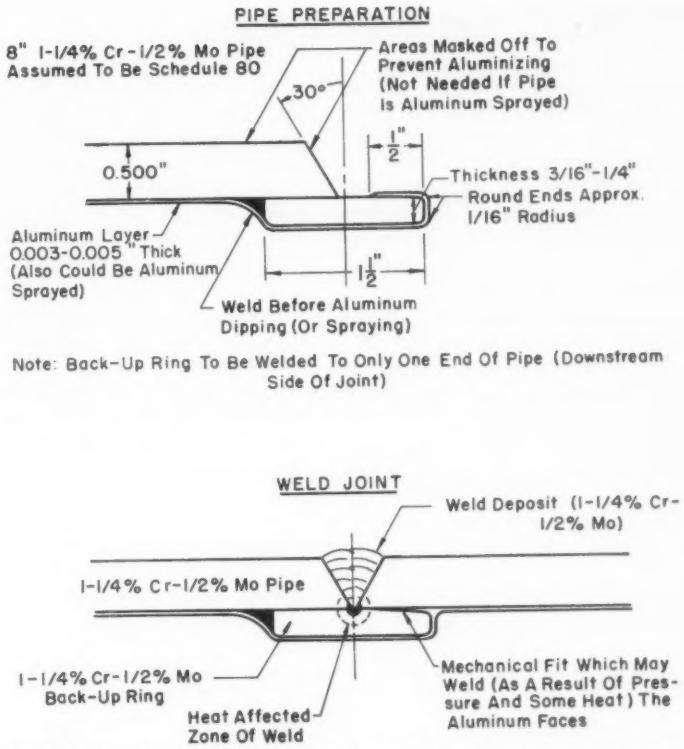
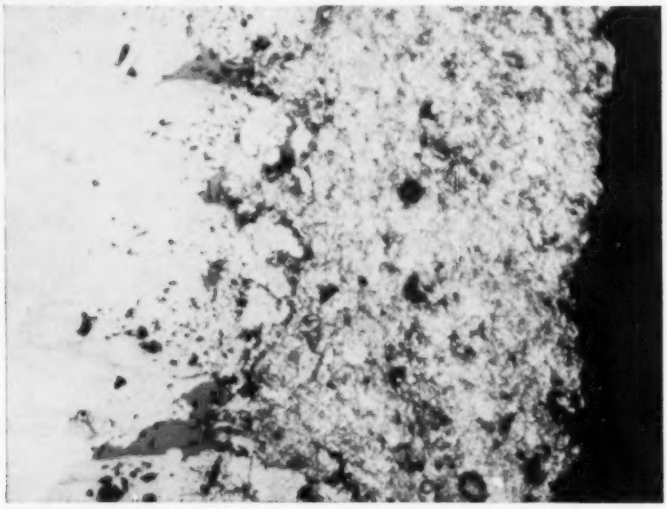

PIPE PREPARATION
8" 1-1/4% Cr-1/2% Mo Pipe Assumed To Be Schedule 80
Areas Masked Off To Prevent Aluminizing (Not Needed If Pipe Is Aluminum Sprayed)
30°
1/2"
0.500"
Thickness 3/16"-1/4"
Round Ends Approx. 1/16" Radius
Aluminum Layer 0.003-0.005" Thick (Also Could Be Aluminum Sprayed)
1 1/2"
Weld Before Aluminum Dipping (Or Spraying)
Note: Back-Up Ring To Be Welded To Only One End Of Pipe (Downstream Side Of Joint)
WELD JOINT
Weld Deposit (1-1/4% Cr-1/2% Mo)
1-1/4% Cr-1/2% Mo Pipe
1-1/4% Cr-1/2% Mo Back-Up Ring
Mechanical Fit Which May Weld (As A Result Of Pressure And Some Heat) The Aluminum Faces
Heat Affected Zone Of Weld

FIGURE 6—How to weld aluminized pipe without losing the continuity of the aluminum coating or contaminating the weld metal with aluminum.



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It appears, therefore, that sprayed and heat-diffused aluminum coatings will have considerable stability in the usual operating temperature range of refinery equipment. Even when the coatings are overheated slightly above the melting point of aluminum, there is an excellent like-

lihood that the worst result will be a surface composed of a layer of aluminum-iron alloy.

If the aluminum coating is thick enough, a certain portion may not become alloyed even with relatively severe temperature treatment. This is shown strikingly by another experimental test. The outer surface of a carbon-steel tube, 5-inch O.D. by ¼ inch wall, was spray-aluminized to a depth of approximately 0.030 inch over one-half of its length, sealed with hydrolyzed ethyl silicate, and thrown into a furnace used for stress-relieving heat treatments on a production basis. During four months in the furance, the tube was exposed to temperatures above 1,300 F. for at least 96 days. The uncoated portion of the steel scaled very badly, whereas the aluminized coated section remained in good condition. Also, it appears that with such heavy coatings, a virtual limiting of the thickness of the alloy bond layer occurs and the remaining aluminum remains substantially unaffected. Figure 5 shows that this exposure did not cause any significant damage either to the outer aluminum layer or to the alloy bond layer.

Fatigue tests on aluminum-dipped specimens of carbon steel and AISI stainless steels Type 410 and Type 304 (along with blanks of undipped materials) indicated that the presence of the iron-aluminum alloy layer reduced the fatigue strength of the carbon steel and of the Type 410 steel approximately 10 to 15 percent, but it did not significantly affect the fatigue strength of the Type 304 steel.

The nature of the surface of a sprayed and heat-diffused aluminum coating on steel may be determined by a spot test. A drop from a solution containing 3 g of potassium ferricyanide, 2 ml of concentrated nitric acid, and 98 ml of water, placed on the coating, will not change color if the material is essentially pure aluminum; will become blue immediately if the surface is base steel; or will assume a gradual blue spottiness if the surface is the iron-aluminum alloy.

Welding Problems on Aluminized Parts. There are some questions concerning the properties of welds made on aluminum-coated parts. To check the physical properties and soundness of welds of aluminized steels, a test butt weld was made between a 6-inch aluminum-dipped elbow and an untreated, 6-inch aluminum-sprayed pipe, both 5/16 inch thick. Both parent metals and the electrode were 2¼ percent chromium-1 percent molybdenum steels. On both parent metals, the aluminum coating extended to the edges of the machined surfaces. The weld was made in a horizontally fixed position with a 600 F. preheat and was allowed to cool slowly, wrapped in asbestos, after welding. The weldment was held at 1,300 F. for one hour and a furnace-cooled to stress-relieve the weldment and diffusion-bond the sprayed aluminum. The weldment then was gritblasted to remove the spatter. In tensile tests of a flat, reduced-section specimen the fracture occurred outside of the weld at a stress of 71,000 psi; the yield strength was 47,000 psi, and the elongation 27 percent in 2 inches. A side bend test specimen bent 180 degrees satisfactorily. Metallographic examination showed that for at least ½ inch on either side of the weld in both the aluminum-dipped and the aluminum-sprayed materials no free aluminum was present, although there was some slight amount of scattered aluminum-iron alloy in this area. It was not known whether this aluminum (and most of the aluminum-iron alloy) was lost during welding or during gritblasting, although the former was suspected. The weld metal was quite clean, and no inclusions were found which could be attributed to possible contamination by the aluminum coatings. A chemical analysis of metal cut from the root pass showed that it contained 0.13 percent of aluminum. This amount of aluminum probably would be ineffective in controlling corrosion by gases containing hydrogen sulfide.

In another test, two samples of carbon-steel piping which had been spray-aluminized internally and heat-diffused were welded together with 1¼ percent chromium-½ percent molybdenum electrodes by a fabricator who claimed that the technique employed caused sufficient aluminum to be retained in the root pass to afford it reasonable resistance to attack by gases containing hydrogen sulfide. One weld was made with the use of a silicone flux backup; after welding, the only internal area which did not have an

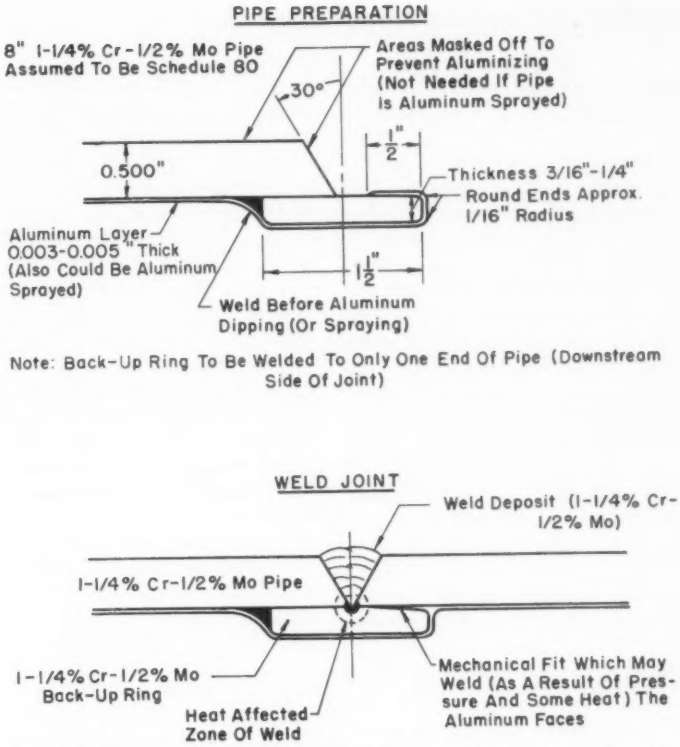
PIPE PREPARATION
8" 1-1/4% Cr-1/2% Mo Pipe Assumed To Be Schedule 80
Areas Masked Off To Prevent Aluminizing (Not Needed If Pipe Is Aluminum Sprayed)
30°
1/2"
0.500"
Thickness 3/16"-1/4"
Round Ends Approx. 1/16" Radius
Aluminum Layer 0.003-0.005" Thick (Also Could Be Aluminum Sprayed)
1 1/2"
Weld Before Aluminum Dipping (Or Spraying)
Note: Back-Up Ring To Be Welded To Only One End Of Pipe (Downstream Side Of Joint)
WELD JOINT
Weld Deposit (1-1/4% Cr-1/2% Mo)
1-1/4% Cr-1/2% Mo Pipe
1-1/4% Cr-1/2% Mo Back-Up Ring
Heat Affected Zone Of Weld
Mechanical Fit Which May Weld (As A Result Of Pressure And Some Heat) The Aluminum Faces

FIGURE 6—How to weld aluminized pipe without losing the continuity of the aluminum coating or contaminating the weld metal with aluminum.

aluminum coating was that of the first pass. The first pass of the other weld was made by the TIG (tungsten inert gas) process with the use of an argon purge. In this weld, some difficulty was reported in obtaining fusion to the aluminum coating. Both weldments were allowed to cool to room temperature and then were stress-relieved at 1,325 F. to 1,350 F. for one hour. Metallographic examination of the two weld joints indicated that both were sound. Corrosion tests in a hydrogen sulfide-hydrogen atmosphere (concentration ratio 1.5×10^{-3}) are being conducted to determine the relative rates of corrosion of the carbon steel, the root pass of the weld, and the crown of the weld. However, the fabricator states that the root pass may contain anywhere between 3 and 10 percent of aluminum. From published data,[5] this range of aluminum may be too broad. For example, even with 3 percent of aluminum, the resistance to hydrogen sulfide corrosion is the same as for unalloyed steel. It appears, therefore, that a minimum of 7 percent of aluminum would be required to offer reasonable corrosion resistance under these conditions.

One technique which was employed to good advantage in welding aluminum-dipped tubes for another reformer utilized a specially prepared backing ring which provided for a continuous aluminum coating across the weld and prevented the pickup of aluminum in the root pass. The details on the use of this backing ring are given in Figure 6.

Originally presented by A. Dravnieks, Standard Oil Co. (Indiana) before the API Division of Refining, New York, May 27, 1959, under title "Aluminizing Reduces Refining Sulfidation and Oxidation."

ACKNOWLEDGMENT

In the preparation of this paper, considerable information and assistance were supplied by the engineering staffs of the various Standard Oil Company (Indiana) refineries and by A. W. Schroeder of Chicago Metallizing Corporation; their help is gratefully acknowledged.

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More About Corrosion

CORROSION RATES in sulfide scaling of ferrous alloys have been obtained from continuous-flow laboratory measurements under hydrorefining conditions. These conditions included hydrogen sulfide partial pressures of 0.3 psi to 150 psi in hydrogen at total pressures to 600 psi. Effects of temperature were investigated over the range of 600 F. to 1,050 F. for exposure periods of several hundred hours. Feed streams used consisted of hydrogen sulfide-hydrogen mixtures and additions of either desulfurized gas oil or platformate. Corrosion behavior of organic sulfides without added hydrogen sulfide was studied. Analysis of the rate data has led to a graphical representation of corrosion rates that may be expected in long-term operation, see Figures 1 and 2.

Principal variables which determine corrosion rates of steels are hydrogen sulfide pressure, temperature, and composition of steel. No effect on corrosion was observed on reducing hydrogen pressure from 600 psia to 60 psia.

Hydrocarbon exerted a depressing effect on corrosion at 700 F. but not at 900 F. Organic sulfides were found to contribute to corrosion only to the extent to which hydrogen sulfide was produced by their decomposition.

Predictions from these curves agreed well with available reformer data, but were conservative when compared with rates observed under mildly corrosive hydrodesulfurizer conditions.

("Sulfide Scaling Under Hydrorefining Conditions," W. H. Sharp; E. W. Haycock, Shell Development Co., Emeryville, Calif.)

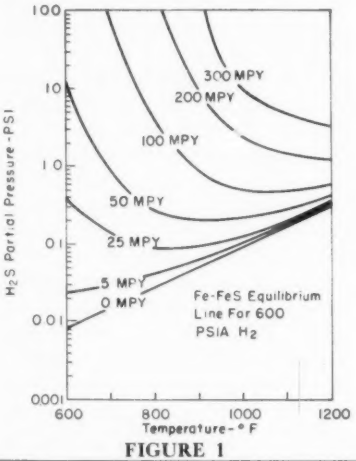

FIGURE 1

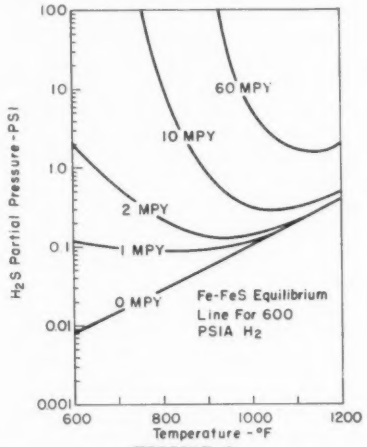

FIGURE 2

Inhibitor Mechanism Studied: The fundamental mechanism of corrosion inhibition is not too well understood. This paper gives fundamentals and covers the adsorption properties of amines.

("Electrochemical Studies of the Fundamental Mechanism of Corrosion Inhibition—The Adsorption Properties of Aromatic Amines," E. Blomgren and J. O'M. Bockris, University of Pennsylvania, Philadelphia).

Clad Steel Successful for High Temp. Service: Physical tests of several types on flat plate specimens and on welded cylinders of Type 304 stainless clad into carbon steel support conclusions based on service data that clad steels are good materials for high temperature conditions.

("Stresses In Clad Steel In High-Temperature Corrosive Environments," W. H. Funk, Lukens Steel Co., Coatesville, Penn.)

Extraction Goes After High Octanes

The Udex extraction process is adapted to separate the high from the low octane components. Here are some schemes for increasing the octane of your gasoline blend

H. W. Grote and D. B. Broughton
Universal Oil Products Company, Des Plains, Ill.

THE UDEX process is a liquid-liquid extraction process developed originally to separate benzene, toluene, and mixed xylenes in high purity from stocks such as reformed naphthas. More recently, the process has been adapted to the separation of the high from the lower octane components for gasoline blending. Since the high-octane aromatic concentrates produced by extraction need not be of high purity, the investment and operating costs of a Udex unit for octane segregation will be somewhat lower than for a unit to produce chemical grade aromatics.

Octane Ratings of Saturates. All catalytic reformates contain non-aromatics boiling over wide range. The octane ratings of broad cuts of these components roughly parallel the average boiling points of the cuts, with the highest boiling fractions having the lowest octane ratings. The use of a series of superfractionators would allow separation of narrow cuts of high octane rating even in the higher boiling ranges. Because of the high investment and operating costs involved, this technique is excluded from consideration here.

The variation of octane rating with boiling range of the non-aromatics in a catalytic reformate is shown in Table 1. These data were obtained by laboratory separation of aromatics from a Platformate of 81.7 Research clear octane number, followed by fractionation of the non-aromatic portion into five equivoluminal cuts. Although these fractions are all inferior in antiknock properties to the aromatic concentrate, which contained 97.0 percent by volume of aromatics and had a Research clear octane number of 105.9, there is a large variation in octane number between the lightest and heaviest fractions. The octane numbers, calculated on the basis of linear blending, for blends of the two, three, and four lightest cuts are also shown in Table 1.

TABLE 1
Properties of Paraffin-Naphthenes

Fraction	Vol. %	TBP, °F	F-1 O.N., Unleaded		
1	0 to 20	136 to 195	77.4	65.9	
2	20 to 40	195 to 332	54.4		57.0
3	40 to 60	232 to 250	39.2		
4	60 to 80	250 to 294	16.0		48.6
5	80 to 100	294 to>370	0.0		
1 to 5	0 to 100	136 to>370	37.4		

Blends of Saturates with Aromatics. From a particular catalytic reformate, a product of given octane number can be obtained by blending the total aromatics with the various paraffinic fractions in many different ways. Obviously, the best way to obtain a high proportion of high-octane product (other than the economically prohibitive use of super-fractionated isoparaffinic cuts) would be to use the lowest boiling paraffin fractions available for blending with the aromatics.

In order to bracket the ranges of operation of commercial Udex units, two types of octane blending studies have been made with the use of the cuts characterized in Table 1. In the first series the aromatic concentrate was blended with various proportions of the total saturates. In the second the aromatic concentrate was blended first with the lightest saturate fraction in the proportions produced, then with saturate fractions 1 and 2 in the proportions produced, and so on.

The results of this study are shown in Table 2. The last column repre-

TABLE 2—Octane Ratings of Saturate-Aromatic Blends

Aromatics in Blend (Vol. %)	F-1 O.N. UNLEADED		
	Aromatics Plus Total Saturates	Aromatics Plus Light Saturates	Residual Saturates
0.0	37.4	....	....
46.9	81.7	....	....
52.4	87.6	88.6	0.0
59.5	90.7	94.4	8.0
68.8	96.5	99.0	18.4
81.5	100.8	102.5	27.4
97.0	....	105.9	....

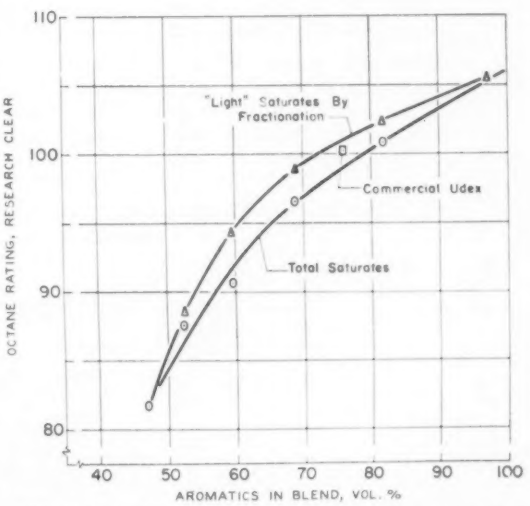

FIGURE 1—Light saturates have better octane ratings than the higher boiling components.

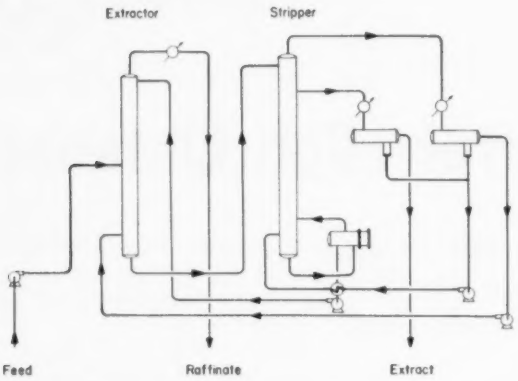

FIGURE 2—The basic Udex arrangement splits reformate into two portions.

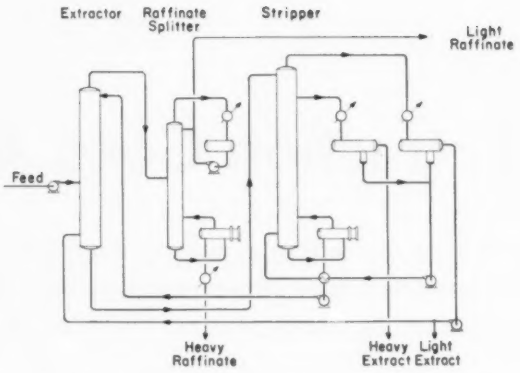

FIGURE 3—A raffinate splitter segregates the more desirable low-boiling fractions.

sents the octane number of the residual heavy saturates which have not been incorporated into the high-octane blend. These data are plotted in Figure 1 as Research clear octane number vs. aromatic content, for each series of blends. The nonlinear blending characteristics of aromatics and saturates are evident.

It can be seen from Figure 1 that a blend having a given octane number will be significantly lower in aromatic content if it is prepared from the light saturates than if prepared from total saturates. The use of light saturates is thus preferable because higher proportions of a blend of a given octane number can be obtained from the reformate. Additionally, it would be expected that blends having lower aromatic contents would have better burning characteristics. To illustrate, a blend having a Research clear octane number of 100 would contain 78.5 percent of aromatics if prepared from total saturates, but only 72.0 percent of aromatics if prepared from light saturates. Correspondingly, the yield of high-octane blend would be 9 percent higher if prepared by blending the light saturates with the total aromatics available.

This particular Platformate, if split in accordance with the upper curve of Figure 1, would yield 65 percent by volume of a blend of 100 Research clear octane number and 35 percent of residual heavy saturates having a Research clear octane number of 20.5. The relatively low proportion of high-octane product is attributable to the low severity of the Platforming operation, the Research clear octane number of the Platformate being only 81.7.

In Figure 1 is shown a point, intermediate between the two curves, corresponding to a commercial Udex extraction of the same reformate used in the blending studies. In order to achieve operation corresponding to the upper curve, it would be necessary to operate the extraction system to produce a highly concentrated aromatic extract and to blend this with the lightest fractions of raffinate. There has been recent interest in the production of 95 percent aromatic concentrates to allow the upper curve to be approached. This type of operation, however, is somewhat more costly; and, in general, an economic compromise such as represented by the operating point shown in Figure 1 has been accepted.

Various modifications of the Udex flow pattern have been used to approach the upper curve of Figure 1 in an economical fashion. The method most suitable will depend on the particular circumstances of each case. In the following sections several flow schemes used in commercial units and pilot plants, together with the corresponding operating results, will be described.

Basic Flow for Udex Extraction. Figure 2 presents the basic arrangement, in which the reformate is split into one extract and one raffinate product. In this system, the distribution of light and heavy saturates between extract and raffinate is controlled simply by the natural selectivity of the solvent. Operating data

TABLE 3—Commercial Udex Results
(Flow of Fig. 2)

	Feed	Raffinate	Extract
Yield, percent by volume	100	48	52
Properties			
Gravity, deg API	49.5	64.8	35.6
Aromatics, percent by volume	47.0	8.0	82.3
F-1 O.N., unleaded	83.1	43.7	103.1
Boiling range, deg F:			
IBP	200	200	212
10 percent point	222	214	245
50 percent point	259	238	288
90 percent point	332	318	340
EP	416	426	400

TABLE 4—Commercial Udex Results
(Flow of Fig. 3)

	Feed	RAFFINATES		EXTRACTS		High-Octane Blend
		Light	Heavy	Light	Heavy	
Yield, percent by volume	100.0	13.9	34.0	6.9	45.2	66.0
Properties						
Gravity, deg API	52.1	76.6	63.8	82.2	36.7	47.5
Aromatics, percent by volume	39.6	0.0	3.9	7.2	79.2	53.8
ASTM octane number (D 908, Research Method):						
Without TEL addition	80.2	57.1	25.0	79.6	102.3	94.9
With addition of 3 ml TEL per gal	93.3	....	....	95.4	104.6	100.1
Boiling range, deg F:						
Initial boiling point	128	115	222	93	188	120
10 percent point	193	145	250	105	255	173
50 percent point	273	190	270	120	300	274
90 percent point	335	235	310	189	350	341
End Point	390	280	390	260	397	400

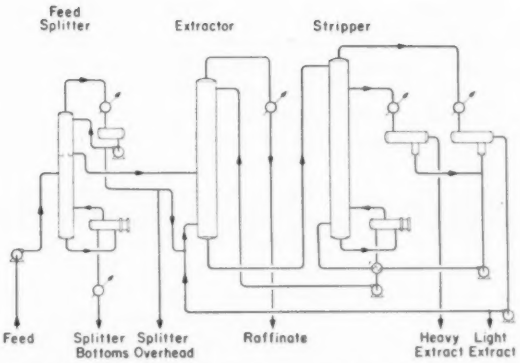

FIGURE 4—The load on the extraction system can be reduced by adding a feed splitter.

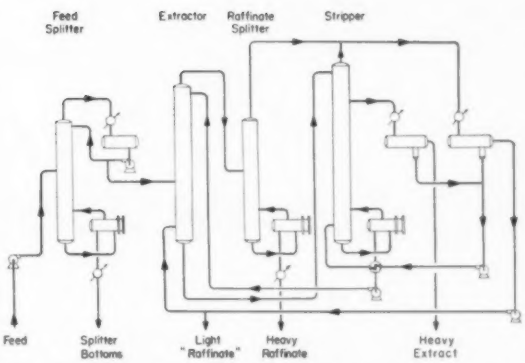

FIGURE 5—Another possibility is to incorporate both the raffinate and the feed splitters.

from a commercial unit using this flow are given in Table 3. The small amount of aromatics remaining in the raffinate will be largely the high-boiling aromatics because these are less soluble in the solvent than the low-boiling members of the series.

Raffinate Splitting Added. In the flow scheme of Figure 3, a splitter column on the raffinate stream has been added to the basic system of Figure 2. The function of this column is to recover the low-boiling fractions of the raffinate for incorporation into the high-octane blend, and thus to obtain a sharper split of low- and high-boiling saturates between high- and low-octane products than possible in the basic flow scheme. A minor portion of the extract is withdrawn as so-called light extract from the extractor reflux stream.

Commercial operating data from a unit using the flow of Figure 3 are presented in Table 4. The high-octane blend represents the combined light extract, heavy extract, and light raffinate. On comparing the octane number and aromatic content of this blend with the curves of Figure 1, it is seen that this point lies above even the upper curve. This is the result of a higher concentration of light paraffins in the feedstock than in the stock on which Figure 1 was based. The low quality of the heavy raffinate is shown by the fact that its octane number is 32 units lower than that of the light raffinate, in spite of the higher aromatic content of the heavy raffinate. The selectivity of the solvent for lighter paraffins, as compared with heavier, results in the production of a light extract (identical in composition with the reflux to the extractor) which is lower boiling than the light raffinate. It will be noticed that the extractor reflux stream is low in aromatic content. This is a desirable condition because light paraffins are more effective in displacing heavy, low-octane paraffins from the solvent than are aromatics.

Feed Splitting Added. In the flow scheme represented by Figure 4, the basic flow of Figure 2 has been modified by addition of a feed splitter column ahead of the extractor. The bottoms stream from the splitter is used directly for blending into the high-octane product; the sidecut stream constitutes the feed to the extractor; the overhead stream is partly withdrawn for blending into the high-octane product and the remainder is added to the extractor reflux stream.

The function of the splitter is to reduce the load on the extraction system by diverting some of the high-

TABLE 5—Commercial Udex Results
(Flow of Fig. 4)

	Feed	Raffinate	Splitter Overhead	Splitter Bottoms	Light Extract	Heavy Extract	High-Octane Blend
Yield, percent by volume	100.0	40.9	9.4	15.1	6.6	27.9	59.0
Properties							
Gravity, deg API	53.5	71.1	81.1	34.0	70.5	37.1	43.3
Aromatics, percent by volume	38.6	2.5	4.5	93.7	17.8	79.6	64.3
ASTM octane number (D 908, Research Method) without TEL addition	83.2	45.0	76.8	102.4	81.9	103.4	99.3
Boiling range, deg F:							
Initial boiling point	133	154	106	298	108	181	126
10 percent point	185	187	118	308	126	228	181
50 percent point	239	214	133	322	151	253	264
90 percent point	307	249	168	355	205	286	322
End Point	365	294	205	431	270	327	382

TABLE 6—Pilot-Plant Udex Results
(Flow of Fig. 5)

	Feed	Feed Splitter Bottoms	Extract	Light Raffinate	Heavy Raffinate	High-Octane Blend
Yield, percent by volume	100.0	8.4	40.1	16.0	35.5	64.5
Properties:						
Gravity, deg API	49.1	25.1	31.6	85.4	68.1	41.3
Aromatics, percent by volume	53	97.2	97.2	4.7	2.1	74.2
ASTM octane number (D908, Research Method) without TEL addition	88.1	....	109.4	81.3	36.3	101.4
Boiling range, deg F:						
Initial boiling point	120	368	227	83	198	....
10 percent point	186	373	257	91	212	....
50 percent point	250	384	284	122	235	....
90 percent point	326	420	322	147	290	....
End point	408	516	356	160	348	....

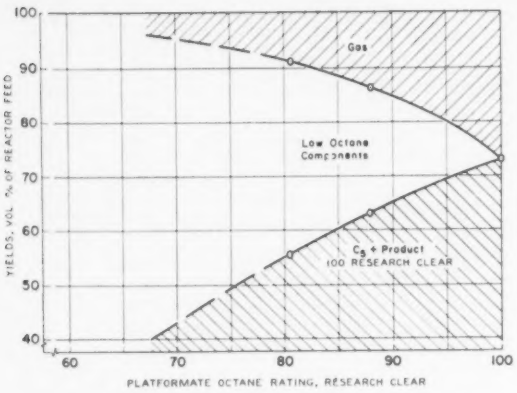

FIGURE 6—A higher octane reformate yields more 100 F-1 octane material, but the total liquid yield is less.

octane components of the feed directly to the high-octane product. It also serves to produce a light paraffin stream desirable as extractor reflux for the purpose of displacing heavy paraffins from the solvent.

The heavy fraction of Platformate is characterized by high aromatic content and high octane number. Inasmuch as the paraffin content of this fraction is so low, little advantage is gained by subjecting it to extraction. A significant reduction in the load on the extraction system is obtained by eliminating this fraction from the feed because the heaviest aromatics are the least soluble in the solvent and, therefore, the most expensive to recover. The light paraffins, as such, are desirable in the high-octane product, and the load on the extraction system is further reduced by removing a portion of these from the feed.

Commercial operating results from a unit using the flow of Figure 4 are presented in Table 5. The high-octane blend is made up of splitter overhead, splitter bottoms, light extract, and heavy extract. In this operation, the aromatic content of the light extract is somewhat higher than in the previous examples because of the removal of some light paraffins from the extractor feed. The boiling range of the raffinate indicates that it still contains some light paraffins which would probably be desirable in the high-octane blend.

Both Feed and Raffinate Splitting Added. In the flow scheme shown in Figure Five, the basic flow of Figure 2 has been expanded by addition of both a feed splitter and a reffinate splitter. The feed splitter serves to divert the high-boiling, highly aromatic portion of the feed directly to the high-octane product, and the raffinate splitter to recover light saturates from the raffinate for the same purpose. This flow scheme will give a sharper split of light and heavy saturates between high- and low-octane products than the flow of Figure 4. The light "raffinate" product is actually a mixture of light raffinate and overhead product from the stripper.

Results of pilot-plant operation with the flow of Figure 5 are presented in Table 6. The high-octane blend represents combined feed splitter bottoms, heavy extract, and light raffinate. The aromatics in the light raffinate are no doubt derived from the stripper overhead stream. Inasmuch as both the feed splitter bottoms and the heavy extract contain only 2.8 percent of saturates, the saturates in the high-octane blend will be almost entirely those produced by fractionation in the raffinate splitter and in the stripper. This operation should, therefore, approach closely the type represented by the upper curve of Figure 1.

Flexibility of Platforming-Udex Combination. The use of extraction in one of the several forms described provides the refiner with flexibility in adjusting his production of various products to market requirements. The nature of this flexibility in conjunction with catalytic reforming is illustrated by a series of tests, the results of which are shown in Figure 6.

To obtain the data for construction of Figure 6, alternate methods of producing a product having a Research clear octane number of 100 from one particular reformer charge stock were considered. The charge stock was Platformed at three different severities and each Platformate was separated into an aromatic concentrate and a saturates portion. The saturates portion was then fractionated into narrow cuts, and successively heavier saturates fractions were blended with the aromatic concentrate in the proportions produced, until the resulting blend had a Research clear octane number of 100.

The data from these tests permitted construction of Figure 6. This shows the yields, based on reformer charge, of a product having 100 Research clear octane number, of low-octane residual saturates, and of gas, as a function of Platformer severity as measured by octane number of the Platformate. It can be seen that the maximum yield of 100-octane product is obtained by reforming directly to that octane number. However, the total yield of liquid products can be increased by reforming at a lower severity and producing 100-octane product by extraction. To illustrate, reforming to an octane number of 88.0 results in a 15 percent increase in total liquid yield above that obtainable by reforming directly to 100-octane product. The positions of the lines of Figure 6 will, of course, be dependent on type of feedstock and quality of extraction.

Disposal of Low-Octane Products from Extraction. If a market is available for the low-octane products—for instance, as jet fuel or specialty solvents—there is an obvious yield advantage obtainable from the use of extraction. Alternatively, the low-octane components can be upgraded by further processing, at the expense of some additional yield of gas.

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Alky Units Revamped for More Output

Older sulfuric acid alkylation units can be revamped now for greater output. Here are four case histories which should give you some useful ideas

A. R. Goldsby and D. K. Beavon
Texaco Development Corporation, New York City

A STUDY of a considerable number of alkylation units employing a sulfuric acid catalyst has shown that most of those installed prior to about 1950 may be expanded at a lower cost than if completely new units were installed. There are several reasons for this. The main reason is that improvements have been made in the process, particularly as applied to the fractionation facilities required, which allow an appreciable increase in capacity without adding relatively expensive fractionation facilities, but by adding relatively inexpensive parts of the unit, such as reactors, refrigeration equipment, and piping.

The aim in expanding existing alkylation units has been not only to increase capacity at a lower cost than for corresponding new facilities, but at the same time to approach as nearly as possible the same results which could be obtained in a new unit of modern design. Just how closely these results can be approached or whether they can be equalled depends on many factors, and the conditions existing for a particular unit.

Improvements. The improvements which have been made in the sulfuric acid alkylation process and which have led to lower investment costs, lower operating costs, improved quality of product, and lower acid consumption fall into four broad categories, which will be discussed briefly.

Auxiliary Equipment. The changes and improvements in the sulfuric acid alkylation process are dramatically illustrated by the fact that in general for motor fuel production a rerun tower for the alkylate product is no longer required. The end point of either total butylene alkylate or mixed propylene-butylene alkylate without rerunning may now be in the range of 350 F to 400 F, whereas formerly it was rather consistently well above 400 F.

The capacity of the fractionation equipment has been increased greatly. Various improvements which have been made in fractionation equipment in general, such as new types of trays, have been applied, of course, to fractionation equipment used in alkylation. However, of even more importance to alkylation is the operation of the deisobutanizer with a lower reflux ratio than used some years ago. Various expedients and flows are also used for increasing the capacity of fractionating towers, such as those for concentrating propane in the feed to the depropanizer and those for concentrating the alkylate in the feed to the fractionation section.

The adoption of centrifugal compressors in place of reciprocating compressors has reduced maintenance and operating costs considerably.

Charge Stocks and Treatment of Product. Charge stocks have become more favorable for alkylation through the widespread use of catalytic cracking and catalytic reforming at the expense of thermal cracking and thermal reforming. More *iso*butane has become available, and the concentration of the propylene and butylenes in the olefin stocks has increased. In general, be-

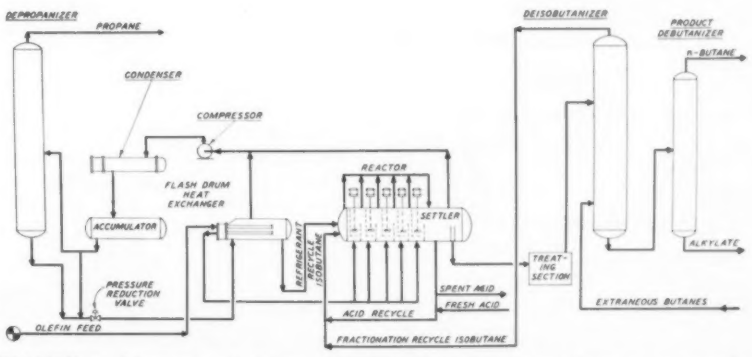

FIGURE 1—Most new alkylation units use either effluent refrigeration or cascade autorefrigeration. Here is a typical unit with cascade autorefrigeration.

cause of the nature of the processes involved and the adoption of positive means for eliminating harmful materials, the charge stocks have been improved in that they now contain less normal butane, propane, water, H_2S (hydrogen sulfide), and mercaptans, which contribute to increased acid consumption.

The product has been improved through better treating processes which include bauxite treating and hot water washing. The caustic washing method was the first method used and is still adequate in many cases.

Process Changes. Some of the major process changes include effluent refrigeration, intensive development of split feed of the olefin charge in a cascade system, better recognition of the importance of the operating variables, and better control and utilization of the variables, and more complete deethanization of propylene charge stocks, and alkylation of mixed butylene-propylene feedstocks.

Reactor Design. The efficiency of the reactors has been improved with a resulting increace in capacity. In addition larger size reactors are now available.

Commercial Processes. Most of the new sulfuric acid alkylation units, as well as those which have been expanded in recent years, use either effluent refrigeration or cascade autorefrigeration. A brief description will be given of these before going into a discussion covering the expansion of four units. For reason of simplicity and clarity, much of the conventional equipment, such as piping, valves, heat exchangers, pumps, and reboilers is not shown on the flow sheets or discussed. Also, since many articles are available on alkylation, the effect of operating variables and detailed operating results will not be given.

Effluent refrigeration is essentially a means of economically obtaining a high *iso*butane concentration in the alkylation reaction mixture with a substantially reduced amount of conventional fractionation. The hydrocarbon portion of the reaction mixture or hydrocarbon effluent from the reactor after separation from the acid in the settler becomes the refrigerant used in the cooling elements of the reactor, and hence the term effluent refrigeration. With effluent refrigeration usually as much as 50 percent or more of the total *iso*butane recycle may be supplied by the refrigerant recycle and only 50 percent or less by conventional fractionation.

Cascade Autorefrigeration uses an integrated reactor which has a plurality of reaction zones and a settler —all in one vessel. A typical flow is shown in Figure 1. The number of reaction zones will vary from two to eight, depending on the capacity desired. The reaction temperature is controlled by the evaporation of light hydrocarbons directly from the sulfuric acid-hydrocarbon reaction mixture. Hence, cooling elements within the reactor are not required. The hydrocarbons and acid flow in series or cascade through the reaction zones with the olefin feed entering each zone in parallel.

Unit A—Effluent Refrigeration. A unit designed in 1941 for approximately 5,200 barrels per operating day of debutanized alkylate from butylenes, amylenes, di*iso*butylene, and only a small amount of propylene was expanded to produce 7,600 barrels per operating day from mixed propylene-butylene feed with the propylene amounting to as much as 90 percent of the olefin feed. The unit was converted from closed-cycle propane refrigeration to effluent refrigeration with utilization of most of the old equipment. Two new 3,280-hp compressors were required.

The unit was originally equipped with six vertical contactors with bayonet-type tube bundles. The six reactors were retained in the revamp and they had already been equipped with improved U-tube bundles. It was desired to use the original and existing depropanizer (6-foot diameter), so a scheme was developed to concentrate the propane in the feed to the depropanizer from the effluent refrigeration system. In addition, the tower was retrayed and the condenser area doubled. The original 8-foot deisobutanizer was inadequate for certain feedstocks even before the expansion, and had been replaced prior to the conversion by a 13-foot, 70-tray tower. Changes in lines and a doubling of condenser capacity on the product debutanizer were about all the changes required in the product debutanizer and final fractionator. The final fractionator was retained, since the alkylate was to be used in aviation gasoline.

Three pairs of reactors are operated in series on the acid and in parallel on the hydrocarbon, with a

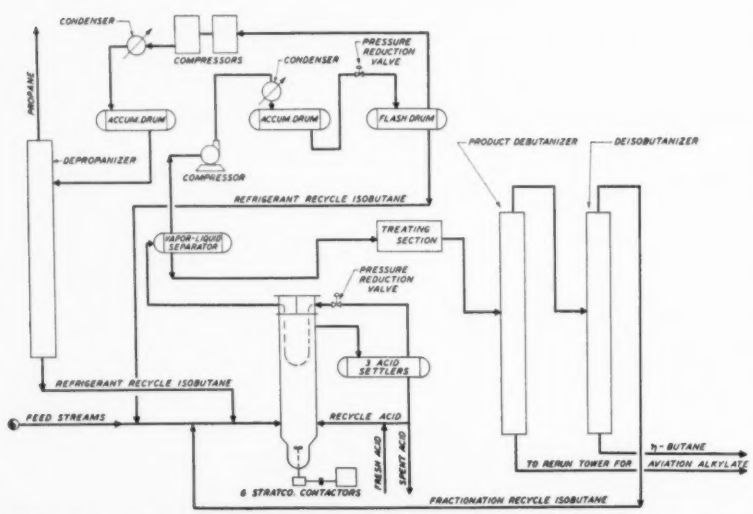

FIGURE 2—By switching to effluent refrigeration, this unit was revamped to up its output.

settler for each pair of reactors. A single, large vapor-liquid separator is used with vapor and liquid entering it from all six reactors.

Although Unit A has six reactors and three settlers, it will serve the purpose and simplify it greatly to describe the flow for only one reactor and one settler.

Referring to Figure 2, the reaction mixture passes from the reactor into the settler, and the hydrocarbon effluent from the settler goes through a pressure-reduction valve into the vertical U-tube bundle in the reactor. The resulting vapor and liquid enter the vapor-liquid separator.

The liquid from the bottom of the separator contains alkylate product, and after passing through a treating section, is sent to the fractionation section and handled in a conventional manner.

The vapor leaving the top of the separator, after passing through a knockout drum, flows in parallel to two new centrifugal compressors capable of compressing the vapor from 0 to 130 psig. The compressed vapor after being condensed and cooled to about 100 F. passes through a pressure-reduction valve into a flash drum operating at less than 5 psig. This results in a liquid temperature of approximately 15 F. to 20 F. in the flash drum. This liquid is largely *iso*butane and is recycled to the alkylation reactor. The vapor from the flash drum passes to the two old 1,000-hp reciprocating compressors which were used for the propane refrigeration prior to the conversion. The compressed vapor after being condensed, cooled, neutralized, and dried is charged to the depropanizer at about 90 F. The depropanizer bottoms containing approximately 90 to 93 percent *iso*butane are cooled and recycled to the alkylation reactor.

Unit B — Effluent Refrigeration. Two closed-cycle, propane-refrigerated units, one with two reactors and one with four reactors, with common fractionation facilities were available. The two units had a combined capacity of approximately 3,200 barrels per operating day from butylenes. There were insufficient refrigeration and fractionation facilities for the desired quality of product and acid consumption at 4,800 barrels per operating day, with

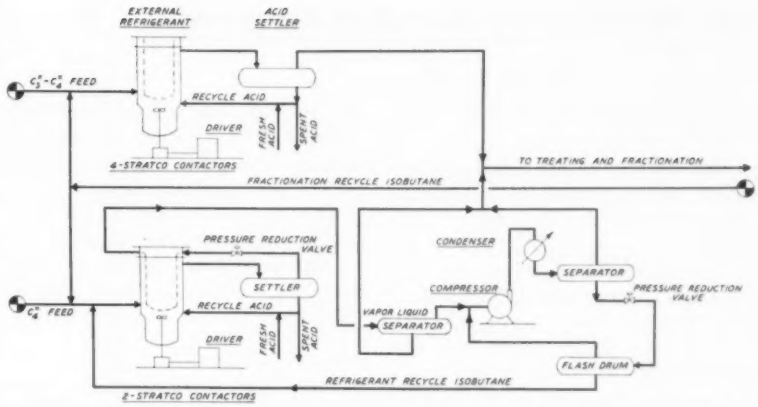

FIGURE 3—This unit has two main flows. One is for a butylene charge while the other charges a propylene-butylene mix.

the increase in production to be achieved by alkylating propylene.

It was found that the new requirements could be met at a minimum cost by converting the two-reactor, closed-cycle, propane-refrigeration unit to effluent refrigeration and operating it on butylenes at approximately 1,600 barrels per operating day, and operating the four-reactor unit as formely with closed-cycle propane refrigeration but on a mixed olefin feed of 50 percent propylene and 50 percent butylenes at approximately 3,200 barrels per operating day. The major new equipment required was an additional compressor of 800-hp capacity. With the new flow, all of the refrigerant recycle *iso*butane is used on the effluent-refrigeration butylene unit, while the fractionation recycle *iso*butane is split as desired between the two units. Common treating and fractionation sections for the two units are used as before the conversion.

It will be noted from Figure 3 that the flow for the lower portion of the unit with effluent refrigeration is substantially the same as previously described in connection with Figure 1. However, since little propylene is alkylated in this part of the unit, propane can be purged as a gas-vent stream which is absorbed in the liquid flowing to the treating section.

The flow of the closed-cycle unit in the upper left portion of Figure 3 is quite simple and conventional. The entire hydrocarbon effluent from the acid settler of the closed-cycle unit and the liquid from the vapor-liquid separator from the effluent-refrigerated unit (plus dissolved gas as noted) are sent to the treating and fractionation sections for handling in a conventional manner.

Unit C—Cascade Autorefrigeration. The expansion of Unit C was so simple as far as the flow sheet is concerned that Figure 1, which has already been mentioned, may be used for reference. The flow of Unit C is substantially the same as in Figure 1.

A four-zone cascade reactor was available which was designed for 2,185 barrels per operating day of total alkylate from mixed propylene, butylene, and amylene feed with 89.5 percent of aviation alkylate of 148.5 PN (with addition of 4.6 ml TEL). It was found that it could be expanded rather simply to produce 3,815 barrels per operating day of total alkylate with 95.1 percent of aviation alkylate of 151.4 PN (with addition of 4.6 ml TEL) when alkylating approximately 46 percent propylene and 54 percent butylenes. The major changes required in the expansion were as follows:

- The reactor was modernized and expanded by adding two additional reaction zones, making a total of six. It was not necessary to increase the over-all size of the reactor-settler vessel, as there was surplus capacity in the settler section.

- The capacity of the autorefrigeration system was increased by adding a new centrifugal compressor of 1,000 hp, which is operated in parallel with the old centrifugal com-

pressor of 1,200 hp. Condensing capacity was also added.

- The capacity of the deisobutanizer tower was increased by modifying the trays, reboiler and reflux condenser.
- The capacity of the alkylate rerun tower was increased by adding a small preflash tower.
- As a part of the expansion the reactor hydrocarbon effluent treating system was changed to bauxite treating.

Unit D—Cascade Autorefrigeration. The expansion of Unit D also was so simple that as far as the flow sheet is concerned, Figure 1 may again be used. It was operated on butylenes before the conversion, and the expansion was for a predominantly butylene feed.

The existing reactors and compressor were not used in the expansion because such a large increase in capacity was desired. The capacity was increased for approximately the same quality of product from 1,500 barrels per operating day of total alkylate to 7,200 barrels per operating day. At a somewhat higher quality, 107.4 Research octane number, with the addition of 3 ml TEL per gallon on aviation fraction, the increase was from 1,500 to 5,250 barrels per operating day.

The major changes which were made to increase the capacity are for the most part similar to those made for Unit C, and are as follows:

- Two existing reactors were replaced with two of the more modern, five-zone integrated reactors, which are operated in parallel with a common fractionation system.
- The old reciprocating compressor was replaced with a new 2,900-hp centrifugal compressor.
- The capacity of all the fractionation towers was increased by changing from bubble-cap traps to perforated trays.
- The capacity of the alkylate rerun tower was further increased by adding a small preflash tower.
- As a part of the expansion the reactor hydrocarbon effluent treating system was changed to bauxite treating.

Operating Results. Great quantities of operating data are, of course, available from the four units which were revamped. However, except as indicated in a general way previously in the paper, a tabulation of such data showing the operating results would not serve the intended purpose of this paper, since the results depend so much upon such factors as the composition of the olefin charge stock, the production rate in relation to the design capacity, and whether the alkylate is being made for aviation gasoline or motor fuel. We believe it will serve the purpose better to give typical results which may be obtained from modern alkylation units operated under reasonably good conditions. Such results are shown in Table 1 when alkylating butylenes and a mixture of 50 percent propylene and 50 percent butylenes.

In considering the expansion of existing alkylation units and the capacity of alkylation units in general, it should be realized that capacity must be considered in relation to the quality of the alkylate and the gross acid consumption. The production of alkylate from a given unit may be increased greatly, but beyond some point the octane value of the alkylate will decrease, and the end point of the alkylate and the acid consumption will increase. Ultimately, the results will become so poor that the operation is not economical. Thus, the results in Table 1 may be somewhat better or poorer for a given unit depending upon the operating conditions. In general, it has been found to be more profitable to operate under reasonably good conditions, and that explains in a large measure why existing units are being revamped and new units are being installed.

TABLE 1—Operating Results

Total Debutanized Alkylate	Butylenes	50 Percent Propylene 50 Percent Butylenes
ASTM distillation, deg F:		
Initial boiling point	116	114
10 percent point	165	160
50 percent point	222	215
90 percent point	250	248
End point	380	375
Research octane number:		
Without TEL	95.0	93.5
3 ml TEL per gal	108.0	105.0
Acid consumption in lb per gal of alkylate	0.4	0.65
Aviation Alkylate:		
Percent of total alkylate	96	97
End point, deg F	338	338
Research octane number:		
Without TEL	96.0	94.0
3 ml TEL per gal	109.0	106
Supercharge performance number:		
4.6 ml TEL per gal	158	148

Patents and patent applications cover many of the features described or involved in the processes and flows discussed. Information regarding licensing of the processes may be obtained from Texaco Development Corporation. Information which may enable one to determine whether it is better to revamp an existing unit or put in a new unit may be obtained from the engineering and construction companies active in the alkylation field.

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About the Speaker

Dr. A. R. Goldsby is with Texaco Development Corp., New York, where he has specialized in sulfuric acid alkylation processes. Holder of M.S. and Ph.D. degrees from Northwestern University, he joined The Texas Co., in 1936 to conduct exploratory research on fuels. He went with Texaco Development in 1940 and has been there since except for two and a half years with Stratford Engineering Corp., Kansas City, Mo. Dr. Goldsby holds about 175 patents, many dealing with alkylation processes, and he served as chairman, alkylation section, Gordon Research Conferences in 1957.

When Is Delayed Coking Worthwhile?

New developments and techniques in delayed coking permit processing heavier charge stocks. Here are cost data to show the economics of coking

Valentine Mekler and Maurice E. Brooks
The Lummus Company, New York City

THE IMMEDIATE future for the delayed coking process looks bright. The inherent flexibility of the process to handle different charge stocks promises the refiner a solution to the problem of decreasing residual fuel demand and takes advantage of the attractive economics of upgrading residual into more valuable lighter products. In recent years, more attention has been given the design of the heater and coke drums used in the process. Thus longer onstream time efficiencies have been achieved while charging heavier and heavier stocks.

The delayed coking process, its operation and development are extensively described in the literature. The description of the process here will be limited to a minimum, just to tie it in with, and concentrate on, the discussion of process variables, their effect on yields, design of critical equipment, and economics.

Figure 1 shows a simplified flow diagram of delayed coking and fractionating section. The residual charge stock is fed directly to the bottom of the fractionator where material lighter than the end point of desired gas oil is flashed off. The reduced feed combined with the recycle is pumped from the bottom of the fractionating tower to the coking heater. The effluent from the coking heater enters one of the two coke drums. Under the time-temperature conditions in the coke drums, coke is formed and accumulates in the vessel, and the coke-drum overhead vapors enter the lower section of the fractionating tower for separation into gas, gasolines, gas oils, and recycle stock.

Process variables in coking, such as feedstocks, product specifications, recycle ratio, and operating conditions and their effect on the performance of the unit are just as important as variables in any other petroleum process.

At one time the feedstock to delayed coking normally was an atmospheric-reduced crude oil not exceeding 10 to 12 percent by weight of Conradson carbon and representing approximately 30 percent on the crude oil. Now the bottoms from the atmospheric tower may be vacuum flashed to recover maximum gas oil for catalytic cracking. Thus the feedstock to delayed coking may be a vacuum pitch containing in the order of 25 percent by weight of carbon residue. To overcome the problems created by the heavier feedstock, improvements have been made in the design and operation of major equipment.

Flexibility is one of the important features of the delayed coking unit. It can process a variety of feedstocks and produce a number of valuable fractions. Typical charging stocks, operating conditions, yields, and product specifications for some commercial delayed coking units are given in Table I. In this table, equivalent fresh feed is

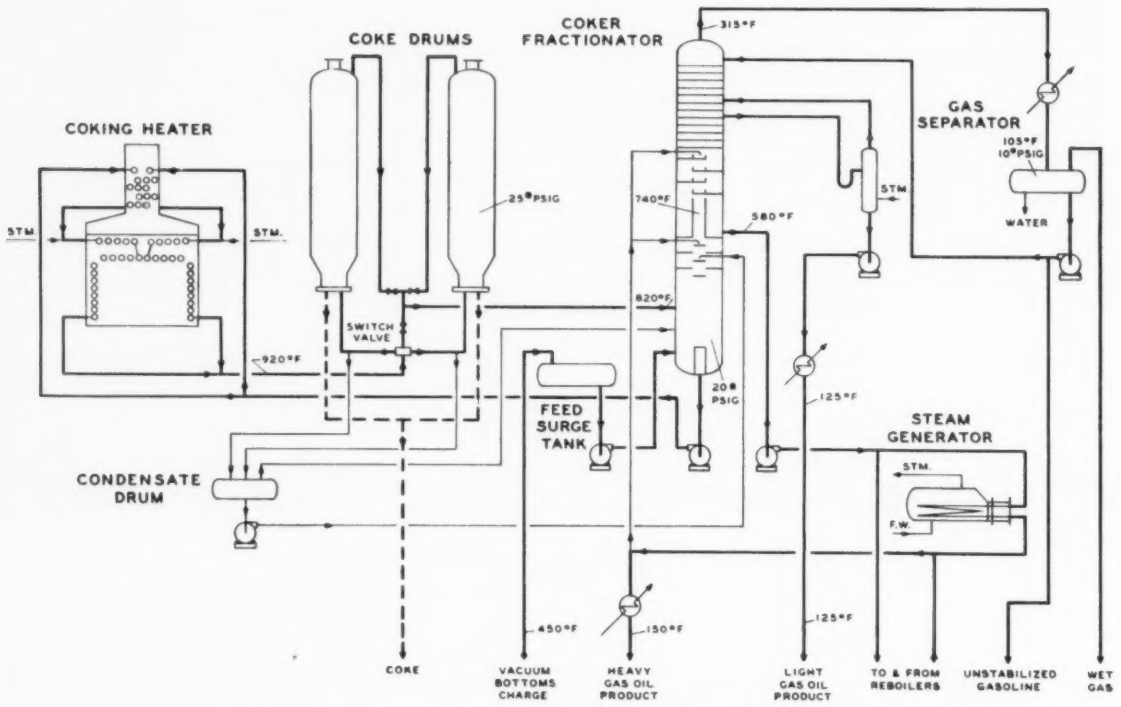


FIGURE 1—Delayed coking is capable of processing a variety of feedstocks.

the total feed to the unit minus the material which would be flashed out during the first pass through the fractionating tower.

Operating conditions in delayed coking, such as temperature, pressure, and recycle ratios, vary within a relatively narrow range. The outlet temperature of the coking heater varies between 900 F. and 960 F., and coke-drum pressures vary between 15 psig and 90 psig. The choice of operating conditions depends primarily on specifications of the charging stock, products desired, and overall refinery operations. Over 90 percent of existing delayed coking units produce heavy gas oil of approximately 950 F. end point and operate at a pressure of approximately 30 psig at the coke drum, at an outlet temperature of the heater of approximately 920 F., and a recycle ratio based on equivalent fresh feed of approximately 0.25.

For maximum yields of heavy gas oils, the delayed coking unit should operate at lower pressure and lower recycle ratio. The end point of such gas oil usually is governed by the maximum allowable content of metal, nitrogen and residual carbon.

TABLE 1—Delayed Coking of Petroleum Residues from Commercial Units

	Mid-Continent	Mid-Continent, Illinois Mix	Arkansas	Illinois	Oklahoma	Venezuela	California
Source of crude oil							
Charge to unit:							
Percent by volume on crude oil	30	....	30	....	....	....	....
Gravity, deg API	20.7	18.9	13.0	12.5	14.0	7.4	12.0
Conradson carbon, percent by weight	....	6.71	15.1	14.8	11.6	19.6	9.6
Sulfur, percent by weight	2.48	0.82	3.0	0.6	1.15	2.76	1.6
Operating conditions:							
Heater outlet, deg F	910	904	914	925	915	920	925
Drum pressure, psig	35	25	30	35	32	25	60
Ratio combined feed to fresh feed	1.30	1.30	1.34	1.25	1.3	1.2	1.30
Ratio combined feed to equivalent fresh feed	0.85	0.98	1.12	1.25	1.3	1.2	....
Yields, percent by weight:							
C_3 and lighter	5.8	6.4	8.1	6.4	7.1	5.6	12.0
Gasoline, C_4—400 F ASTM end point	21.8	....	17.1	21.6	....	17.8	15.7
Light gasoline	....	8.6	....	....	20.5	6.1	....
Heavy gasoline	....	7.2	....	....	....	11.7	....
Light gas oil	56.1	9.9	43.3	46.0	49.5	20.0	35.2
Heavy gas oil	....	51.5	....	....	....	23.7	15 5
Coke	16.3	12.6	31.5	26.0	22.9	32.6	21.6
Product specifications:							
Full-range gasoline end point deg F	400	....	400	400	....	400	390
Light gasoline end point, deg F	....	300	....	....	380	200	....
Heavy gasoline end point, deg F	....	435	....	....	....	400	....
Light gas-oil end point, deg F	....	611	....	....	....	666	720
Heavy gas oil, deg API	28.2	25.5	27.1	29.0	29.4	22.3	10.1
Vacuum Engler end point, deg F	725	950	....	....	850	....	950
Conradson carbon, percent by weight	0.02	0.11	....	....	0.1	0.30	....
Sulfur, percent by weight	1.55	0.56	....	....	0.79	1.57	1.37

Yields. Yields of products vary with the source of charging stock, end point of gas oil desired, recycle ratio, and operating conditions.

Yields of coke are in direct proportion to the Conradson carbon in the feedstock and are approximately 1.75 times the Conradson carbon in the feedstock when processing paraffin stock and producing approximately 950 F. end-point gas oil. When processing a refractory or naphthenic stock, the yields of coke for corresponding end point of gas oil are slightly higher.

In cases where both the Conradson carbon and the API gravity of the feed are not known or not reliable, the relationship between the Conradson carbon in the feedstock and its API gravity can be obtained from Figure 2 for estimating yields of coke. Figure 2 shows such relationship when processing paraffin base stock in delayed coking and producing approximately 950 F. end-point gas oil at an approximate coke pressure of 25 psig.

Coke yields shown in Figure 2 are applicable when relatively clean 950 F. end-point gas oil with a Conradson carbon of not more than 0.3 percent by weight is produced. This 0.3 percent of Conradson carbon in the gas oil is low enough and quite acceptable as a charge stock for catalytic cracking. If a reported yield of coke from a given operation is lower than shown in Figure 2, look for an explanation in the examination of the Conradson carbon content and the end point of the gas oil produced. Invariably, it will be found that when the coke yields are reported to be low, the Conradson carbon in the total gas oil is much higher than the 0.3 percent by weight. Irrespective of the coking process, the ultimate gross yields of coke would be approximately the same for a given end point and Conradson carbon of the gas oil produced.

Figure 3 shows the approximate yield relationship for the four main products when charging paraffin base stock and producing approximately 950 F. end-point gas oil at 25 psig coke-drum pressure. For naphthenic stocks the yields of gas and coke are higher with a corresponding decrease in gasoline and gas-oil yields.

Critical Equipment Design. The understanding of process variables and their effect on the operation and the design of the unit determines the performance, onstream time efficiency, and the economics of the coking unit. A properly designed unit should also have built-in flexibility to adjust the operating conditions for variations of feedstock, capacity, and product specification.

Heater. The most important piece of equipment in delayed coking is the heater. The prime function of a coking heater is to heat the feedstock very quickly to the required outlet temperature and pressure without premature coke formation in the tubes resulting in premature shutdown.

It is well known that in many heaters coke formation takes place not at the end of the coking heater where the temperatures are highest, but at intermediate points in the coil where the temperature is below the outlet temperature.

This coke formation starts in the so-called critical zone of incipient cracking or the critical zone of decomposition. Each stock has its own critical zone of decomposition. If the oil passing through this critical zone is in the liquid state and at relatively low linear velocity, then,

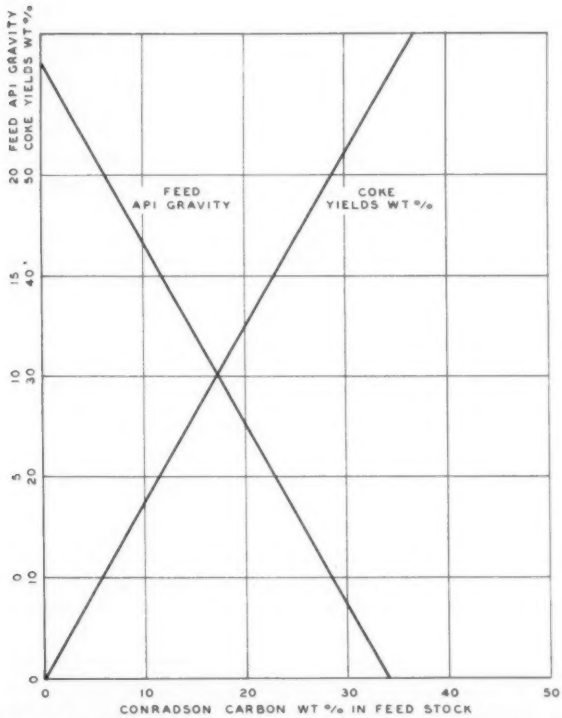


FIGURE 2—The coke yield can be related roughly to the gravity of the feed. In this correlation a paraffin base stock is used to produce 950 F end-point gas-oil at a coke-drum pressure of 25 psig.

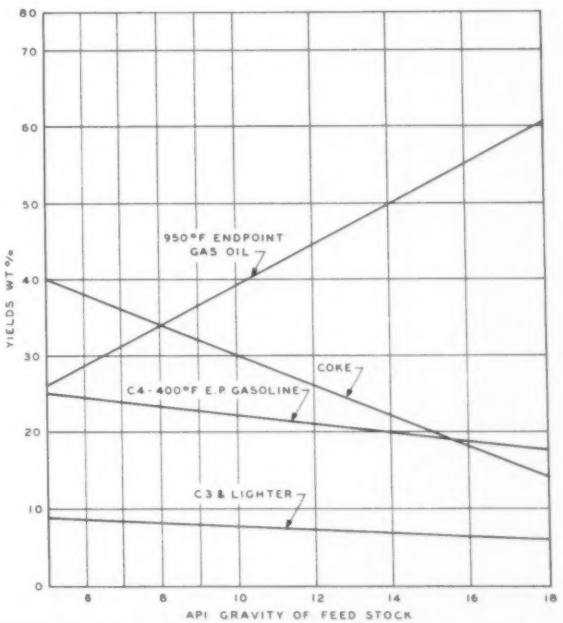


FIGURE 3—The yield of each product from delayed coking can be related to the gravity of the feed.

under the influence of temperature, the slow-moving oil film on the inside surface of the hot tube tends to polymerize and eventually deposits coke in the intermediate portion of the heater, while the tubes toward the outlet are free from coke deposition.

In order to make sure that the heater will not cause coke formation in the intermediate portion of the heater, it is necessary to provide high turbulent motion in the portion of the coil where the zone of critical decomposition takes place.

This turbulent motion or high velocity through the critical zone can be attained by providing such temperature and pressure relationship in the coil as will produce the required vaporization. In practice, it was found that the vaporization of the oil as it passes through the critical zone should be from 5 mole percent to 20 mole percent, depending on the characterization factor (K) of the stock.

Figure 4 shows approximate temperature levels of critical zones of decomposition of residual oils for stocks having various characterization factors. The higher the characterization factor of the stock, the lower the temperature will be at which incipient cracking takes place. Since the temperature range of the critical zone of decomposition will also be lower, this zone occurs farther back in the heater, and coke will deposit there unless sufficient velocity and/or vaporization is provided for in the design of the heater.

For paraffinic stock with characterization factor of 11.8, the temperature zone ranges between approximately 800 F. and 850 F., while for stock with characterization factor of 11.3, this zone lies between 850 F. and 890 F.

Under average temperature and pressure conditions, some very heavy stocks do not vaporize sufficiently to give the turbulent velocity needed to pass through this critical zone without coke deposit in the tubes. In such cases, a controlled amount of steam can be injected at various strategic points to obtain the required velocity.

The amount of steam to be injected varies with the capacity and type of the stock but, in general, is small and will not exceed 1,200 pounds per hour of steam per 10,000 barrel per day throughput.

When the principles outlined previously are applied to the design of the heater, it is possible to establish for any given stock the proper tube diameter, length of coil, and number of streams, to give the necessary temperature, pressure, and vaporization gradient through the zone of critical decomposition, so that the heater will assure successful operation of long duration without coke formation.

This theory of critical zone of decomposition is applicable in the design of any coking, viscosity breaking and similar service heater.

For a given capacity, a heater designed with a low-pressure differential will result in an earlier vaporization and would require less steam injection to reach the critical velocity than a heater designed with a higher differential pressure. By going to high enough pressure differentials, the liquid linear velocity can be made sufficiently high so that injection of steam and vaporization may not be required. However, the heater with low differential pressure and equivalent surface will have fewer passes, less auxiliary piping and instrumentation, lower pumping costs, and lower investment cost.

Coke Drums. Another major piece of equipment in delayed coking is the coke drum. Its main function is to provide enough volume for accumulation of coke produced during the normal cycle of 24 hours. However, in designing a coke drum, it is necessary not only to provide sufficient volume for coke but also to consider the maximum allowable superficial vapor velocity in the coke drum, the minimum free board, and the foaming characteristics of the charge stocks.

These factors determine the mini-

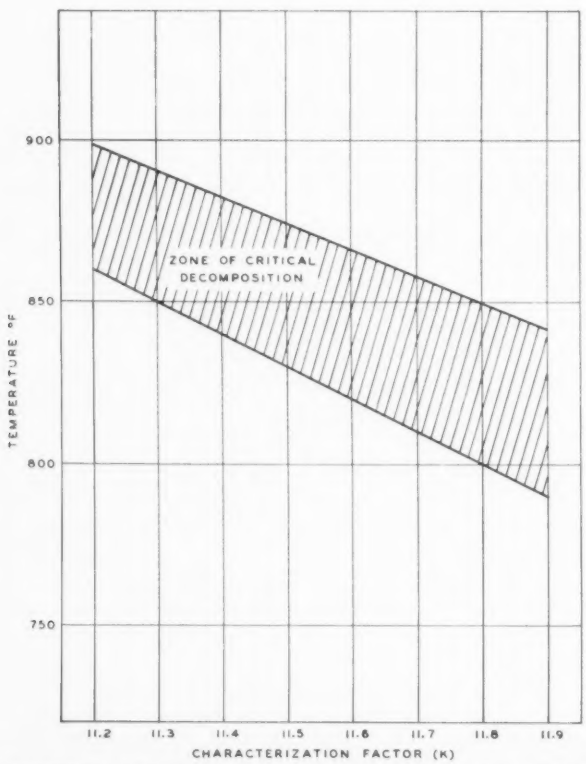


FIGURE 4—Coke formation in a furnace starts in the so-called critical zone.

mum diameter and the height of the coke drum.

High vapor velocity and high foaming characteristics of the charge stocks may cause, at the end of the coking cycle, mechanical carry-over of coke-forming material from the drum into the fractionator, and from there into the heater, which will result in a premature coking of the heater and a shutdown.

With growing capacity and coke production per unit, the size of coke drums increased gradually for the last 25 years from 10 feet in diameter to present-day 20 feet in diameter, and the height of the coke drum from 40 feet to over 80 feet.

There is no reason why the jet water pump and the decoking nozzle could not be designed for decoking a larger—say, 24 feet-diameter—coke drum. In many cases, this would reduce the number of coke drums from four to two, resulting in savings in coke drums as well as expensive switch valves, piping, and all accessory equipment connected with the extra pair of coke drums.

It was reported that, due to sudden changes in temperatures during switches of coke drums, strains and stresses cause numerous mechanical difficulties at the bottom of coke drums and cones which require extensive maintenance and loss of onstream time efficiency.

The most frequently reported difficulties are:

- Distortion of bottom manhole-neck flange.
- Weld cracking between bottom cone and manhole neck.
- Crack formation around cone nozzle attachments.
- Deformation and warping of shell.
- Cracking of internal alloy lining.

Most of these difficulties could be attributed to improper location of nozzles and the method of introducing the effluent from the heater and the cooling water and steam into the cone of the coke drum. On coking units where the effluent from the heater and nozzles for quench water, steam, etc., are introduced through the center of the bottom-cone manhole flange, sudden temperature shock of quenching the coke drum, causing the aforementioned difficulties, is avoided because the relatively cold steam and water do not immediately contact the shell of the cone but, by passing through specially designed inside distributors, are heated up by hot coke to a safe temperature before reaching the side of the shell.

Practically all coke drums require the use of chromium alloy material to resist the corrosive action of the sulfur in the residual oils. Many years of experience have shown that 11 to 13 percent of chrome will provide entirely adequate corrosion protection in delayed coking service. Because of the heavy wall thickness of coke drums, the alloy protection is always provided in the form of applied liners or clad materials.

The methods of construction by which the alloy protection is provided are as follows:

- Integrally clad 11 to 13 percent chrome on carbon or carbon-molybdenum backer plates. Little or no long-term maintenance or repairs are to be expected with these materials.
- Resistance-welded applied liners in which the liner sheets are spot welded to the carbon or carbon-molybdenum backer plates with spot welds on 1- to 1½-inch centers. With this lining method, some routine maintenance during scheduled shutdowns is to be expected.
- Plowthrough applied liners, in which the liner sheet is welded to the carbon or carbon-molybdenum backer by automatic submerged arc welding through the liner sheets into the backer materials. The welds are continuous along the length of the liner sheets and are spaced on about 4-inch centers across the width of the liner sheets. With this lining method, maintenance and repair requirements are expected to be slightly greater than with a resistance-welded liner.
- Strip lining methods in which 3 inch to 4 inch wide strips of liner material are manually welded to the backer plates, using a three-pass manual weld. Experience has shown that maintenance requirements with this lining method are quite high.

The integrally clad, the resistance welded, and the plowthrough methods of construction are all acceptable. Strip lining is not an acceptable method except under most unusual circumstances.

Selection of the proper construction method is a matter of the economics of the particular installation involved. For an installation in which the lowest possible initial investment is required, the least expensive vessel (normally, the plowthrough lining) should be used. For installations in which maximum long-run economy is desired, one should consider paying a premium of approximately 5 percent more for resistance lining over plowthrough, and a further premium of an additional 5 percent for clad over resistance weld.

For backing material, A 285 (carbon steel), A 201 (carbon silicon steel), and A 204 (carbon-molybdenum steel) are all satisfactory. The proper choice of backer material is again a matter of the economics of the particular installation involved. These are all satisfactory materials.

In the selection of both lining method and backer materials, the relative costs of the various possible combinations will vary widely from job to job. The possibility of shop fabrication, rather than field erection, and intangible factors, such as quicker delivery, varying fabricating shop loads, etc., have great influence on the relative costs of these vessels. For proper selection of the possible alternative, a specific economic study should be made in each case.

Operation and Maintenance

Length of Run and Onstream Time Efficiency. The length of run in itself is not as important as the over-all onstream time efficiency. It would appear that the longer the run, the more profitable is the coking operation. However, many factors determine the length of the run and time efficiency, such as characteristics of the charging stock, caliber and experience of the operating personnel and supervision, over-all scheduling of refinery operation, maintenance of the equipment, etc. Depending on the over-all operation of the refinery, the length of run of a coking unit may vary from three months to one year, but most of the refiners schedule their length of run on coking units for a six-month duration and find that it is more economical than to have longer runs which may require a more extensive maintenance and longer shutdown

periods. The number of turnarounds per year for decoking the heater, equipment maintenance, etc., does not affect the economics as much as the total number of days that the unit stays out of operation per year. Most operating units have an on-stream time efficiency of over 90 percent, with some reporting as high as 97 percent efficiency.

TABLE 2—Typical Coke-Drum Cycle

Operation	Hours
Filling with coke	24
Switching drum	½
Streaming out	2½
Water cooling	3
Draining water	2
Hydraulic decoking	5
Headup and test	2
Warmup	7
Spare time	2
Total cycle	48

Time Cycle. Due to daily switching of the coke drums, which disturbs temporarily the equilibrium in the fractionating system, the operation of a delayed coking unit is very sensitive and may result in serious upsets, unless operators are thoroughly familiar with the technique of switching the coke drum, cooling, steaming out, coke handling, and heating up the empty coke drum—in short, all the steps during the entire cycle period and operation. As a result of many years of experience and accumulated know-how, important improvements in the technique of getting the unit onstream, switching of the coke drums, decoking, etc., were introduced. Table 2 shows a typical cycle schedule required for the different steps in a 48-hour time cycle.

Economics of 10,000-BPD Delayed Coker. A 10,000 barrel-per-stream-day delayed coker with a 15 percent Conradson carbon charge stock has been chosen as a basis of evaluating the economics, since such a unit would produce approximately 450 tons per day of coke, which is the practical limit for a two-coke-drum unit with drums approximately 20 feet in diameter and 65 feet in height.

The estimated installed cost of such a unit is $4,750,000. This sum includes the complete coker, the gas plant to recover 90 percent of the butanes and produce a debutanized

TABLE 3—Product Distribution

Basis: Charging 12.4 deg API 15 Percent by Weight of Conradson Carbon Reduced Crude Oil; 330 Stream Days Per Year; Gas Plant Recovery 75 Percent C_3 and 90 Percent C_4

	Barrels Per Stream Day	Percent by Volume	Percent by Weight	Dollars Per Barrel	Dollars Per Stream Day	Dollars Per Year
Production:						
Fuel gas (fuel-oil equivalent)	515	5.2	5.2	0.20 per million	628	207,000
Propane LPG	477	4.8	2.5	2.20	1,050	346,000
Butanes	348	3.5	2.1	4.40	1,530	505,000
C_5—400 F end-point gasoline	2,490	24.9	18.7	3.90	9,720	3,210,000
Coker gas oil	5,000	50.0	45.3	3.78	18,900	6,240,000
Coke, tons per day	450	...	26.2	10.00 per ton	4,500	1,485,000
Total			100.0		36,328	11,993,000

Gross product value per barrel of charge $3.63.

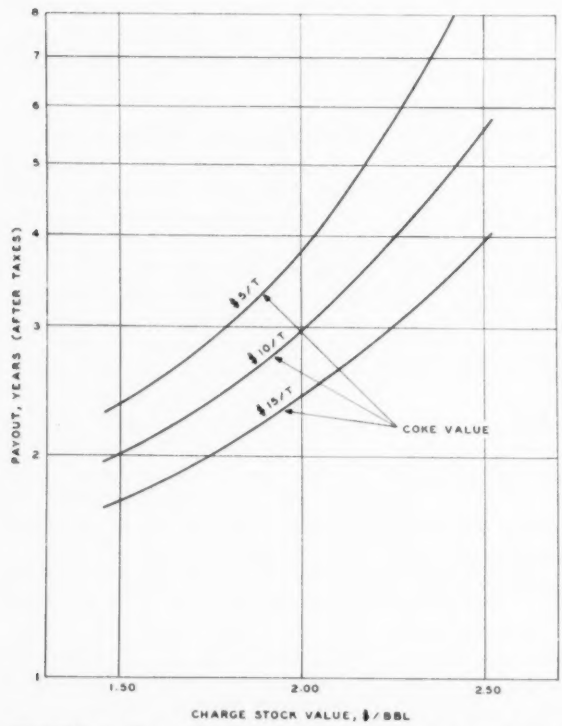


FIGURE 5—Payout period when the coker gas oil is 7 cents per gallon.

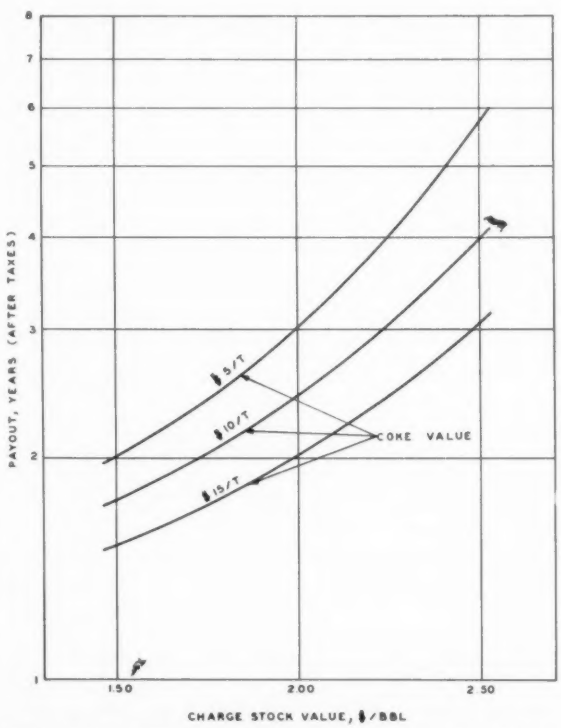


FIGURE 6—Payout period when the coker gas oil is 8 cents per gallon.

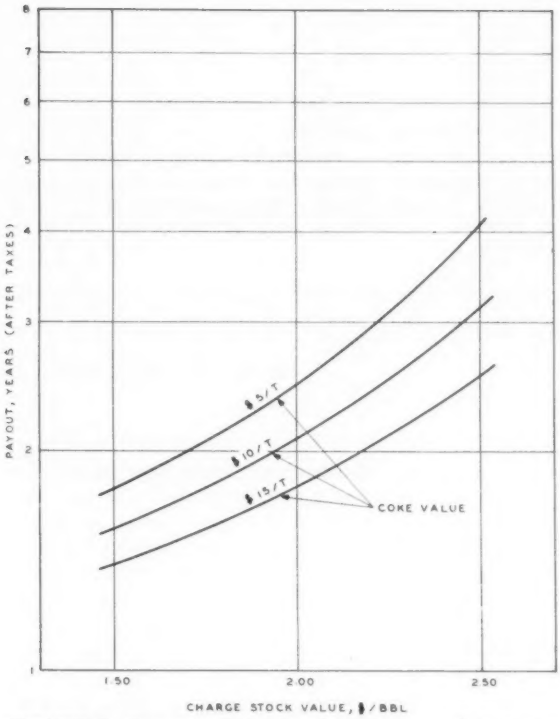


FIGURE 7—Payout period when the coker gas oil is 9 cents per gallon.

About the Speaker

Valentine Mekler is a technical specialist for The Lummus Co. He came to the U.S. from Russia, where he was born in 1921, and received a B.S. degree from the University of Pittsburgh in 1925—then joined Warner-Quinlan Co. From 1927-35 he was with Universal Oil Products Co. as a group leader in charge of process design and operation. Mekler joined Lummus as a process technologist in 1935.

coker gasoline, the decoking system, the coke handling system, and the LPG treating facilities. Offsite facilities are not included. However, utilities costs are charged to the unit.

In Tables 3 and 4 is found the estimated profitability of such a unit. The bases for this profitability study are given in Table 5. As basis for the study, onstream efficiency of 90.5 percent was chosen, which is conservative for commercial operations. Direct and indirect costs have been based on extensive experience and are considered reliable. The product prices chosen may be regarded as realistic present-day averages. For the particular example given, the price for coker gas oil was set at $0.09 a gallon, and for coke at $10 a ton. These prices were then varied to determine their effect on the economics of delayed coking, as will be shown later on.

It is of interest to look at the relative importance of various factors in the economics of coking. From Table 3, it can be seen that the gross product value amounts to $3.63 per barrel of charge. Of this amount, coke and gas contributed $0.51 or 14.1 percent of the total product value. It can be seen that the most important contributors are gasoline and coker gas oil, which contribute $2.86 or 79 percent of the total realization. The coker gasoline has been set at $0.50 per barrel under current prices to allow for upgrading to a salable product. Obviously, the values assigned to coker gas oil are prime factors in evaluating delayed cokers.

Curves found in Figures 5, 6 and 7 relate the value assigned to gas oil, coke, and feedstock value to the payout period which was calculated after federal income taxes but exclusive of working capital requirements and corporate overhead charges. It can be seen that if the feedstock value is $2 per barrel or less, the payout period is attractive even for gas-oil prices as low as $0.07 per gallon and coke at $5 per ton.

At feedstock values above $2.20 per barrel, not only is the payout

TABLE 4—Estimated Profitability

Production Costs:	$/Yr.
Feedstock @ $2.00/bbl	6,600,000
Others (See Table 5)	1,639,000
Total	8,239,000
Net profit before taxes	3,754,000
Income taxes at 52 percent	1,950,000
Net profit after taxes	1,804,000
Payout period after taxes, including depreciation, years	2.08

Total production costs per barrel of charge, $2.49

TABLE 5—Basis of Profitability Study

Production Costs	Dollars	Dollars Per Year
1 Labor:		
Operating: 4 men per shift, at $3.00 per hr	140,000	.....
Decoking: 3 men, one shift, at $2.75 per hr	24,000	.....
Supervision	16,000	.....
		180,000
2 Maintenance at 4 percent of investment	.....	190,000
3 General and administrative expenses at 2½ percent of investment	.....	119,000
4 Insurance and local taxes at 2 percent of investment	.....	95,000
5 Utilities:		
85,000,000 Btu per hr at $0.20 per million Btu	135,000	.....
25,000 lb per hr stream at $0.50 per 1,000 lb (24 hr per day)	99,000	.....
15,000 lb per hr stream at $0.50 per 1,000 lb (5 hr per day)	12,000	.....
12,000 lb per hr stream at $0.50 per 1,000 lb (2 hr per day)	4,000	.....
9,000 gpm water at $0.01 per 1,000 gal	43,000	.....
600 kwh at $0.01 per kwh	48,000	.....
		341,000
6 Handling loss, percent of product value	.....	120,000
7 Interest on half of investment at 5 percent	.....	119,000
8 Depreciation at 10 percent of investment	.....	475,000
Total		1,639,000

period more sensitive to the value of gas oil but the value assigned to coke becomes more significant. Coke prices were assumed at three levels —$5, $10, and $15 per ton. The lower value is representative of a minimum price for coke as a fuel when high in sulfur and containing metal contaminants, which is a function of the feedstock. The higher value is more representative of premium coke when sold for metallurgical and aluminum electrode purposes.

Condensed from a presentation before the American Petroleum Institute, Division of Refining, New York, May 28, 1959. ##

More About Processes

Pilot Plants Guide Refinery Operations. Data from small semiautomatic pilot plants, which are reasonably inexpensive to run and which correlate closely under carefully controlled conditions with actual commercial results, provide a valuable source of accurate information for guiding refinery operations. Examples show how data from small catalytic cracking, hydrodesulfurizing, reforming, and fluid coking pilot plants are used in a number of ways to plan the operation of Tidewater Oil Company's Avon and Delaware refineries.

A description is given of the pilot plants used to furnish refinery simulation data points out the pilot unit's small size, as well as their automatic and safety features. Two of these units are believed unique in the oil industry in that they are run unattended 16 hours a day.

("Guiding Refinery Operation with Small Semiautomatic Pilot Plants," W. M. Miller, Tidewater Oil Company, Associated, Calif.)

Crude Unit Operated At Low pH. Approximately five years ago, The Ohio Oil Company's refinery at Robinson, Ill., lowered the pH on crude-oil overhead receiver waters from an average of 7.5 to 4.3, increased the inhibitor injection into the vapor overhead from 6 ppm to 10 ppm to 10 ppm to 15 ppm. This change to lower pH operations resulted in excellent control of corrosion, cleaner equipment and reduction of ammonia contamination in the hydrocarbon streams.

The clean equipment obtained at the low pH operation has greatly reduced maintenance costs at scheduled turnarounds and permitted longer runs at increased charge rates.

("Processing Crude Oil at Low pH," J. A. Biehl and E. A. Schnake, The Ohio Oil Company, Robinson, Ill.)

Hydrogen Treating Examined. The use of hydrogen treating has gained remarkable impetus in the past few years. The process is used in petroleum refining to obtain significant quality improvement at high yield, with the elimination of older finishing steps.

Hydrogen treating is applied under varying conditions to improve the quality of virgin and cracked naphthas, virgin and cracked domestic heating oils, kerosine, diesel oils, jet fuel, heavy gas oils, lube oils, solvents, and paraffin wax. A remarkable improvement is effected in such properties as color, odor, corrosiveness, burning characteristics, stability against the formation of gums and sludge in storage, and sulfur content. In the longer range the hydrogenation process likely will be applied to residual oils or to whole crude for conversion to lighter and more valuable products, as well as for quality improvement.

As an illustrative example, a description is given of the commercial hydrogen treating operations currently being conducted by Humble Oil and Refining Company. Humble has a very high volume of hydrotreating capacity relative to its crude-oil processing capacity.

("Optimal Utilization of Byproduct Hydrogen in an Integrated Oil Refinery," G. T. Gwin, Humble Oil and Refining Company, Baytown, Texas)

Desulfurize Reformer Feed. The first commercial plants for this new refinery process are now in operation. The process employs a new technique described as "electrostatic mixing" to desulfurize reformer feed stocks. Data is presented to show satisfactory removal of various contaminants such as nitrogen complexes, arsenic, and lead. In addition to electrostatic mixing, the process employs sulfuric acid—either spent alkylation or fresh—as the oxidizing agent.

("Electrostatic Desulfurization of Reformer Feed Stocks," R. J. Phillips and H. G. Napier, Howe-Baker Engineers, Inc., Tyler, Texas)

New Way to Figure Octanes. A new approach for calculating the octane number of a multicomponent blend is available now. The formulas are useful for specific refinery operating and economics calculations and also for industry-wide octane studies.

The method is based on blending deviation data in 135 blends at three TEL levels by both Research and Motor methods. Statistical methods and the extensive use of electronic computers made possible the examination of many equation forms and more than 25 variables. The resulting blend octane formulas take into account differences in octane number, sensitivity, and hydrocarbon type among the blend components. The formulas are very convenient for electronic computer use and are suitable for desk calculation.

("A New Approach to Blending Octanes," W. C. Healy, Jr., C. W. Maassen, and R. T. Peterson, Ethyl Corporation, Detroit, Mich) ##

Exchange Fuel for Power and Steam?

By trading refinery fuel for public utility energy, you can cut capital investments and operating costs. Here's how it's done.

E. J. Hess, Esso Standard Oil Company, New York City
V. E. Kilpatrick and G. H. St. Onge
Esso Research and Engineering Company, Linden, N.J.

THE EMPHASIS today is to provide new refinery facilities at the lowest possible investment compatible with safety and efficient operation, and to operate new and existing facilities in the most efficient manner possible. The electric power and steam facilities can provide a fertile field for investment and operating cost reduction.

The exchange of refinery fuel for electric power and steam produced by a public utility is one method of reducing refinery investment and cost of operation.

CONSIDERING ENERGY EXCHANGE

The Grass Roots Refinery. Design of a new refinery should always consider the long range effects of energy exchange with a public utility. This is true even in undeveloped locations where the existing capability of public utilities is inadequate for the refinery's requirements. If an energy exchange is sufficiently attractive the refinery operation may find it advantageous to arrange long term loans to the utility company which will assure the necessary expansion of equipment and facilities.

In general, the grass roots design should incorporate the principles of energy exchange whenever a reliable public utility company is willing to cooperate.

Existing Refinery Expansion. In existing refineries the pros and cons of energy exchange should be evaluated whenever steam and power requirements substantially increase. Large, old refineries after many years of independent utility operation have found it profitable to effect a fuel-power, steam exchange with a public utility company instead of investing additional funds in steam and power generation.

Equipment Replacements. When large expenditures are required to replace obsolete steam and power generation equipment an attractive alternative may be an energy exchange with a utility company.

Conditions Favoring an Energy Exchange. An energy exchange can be justified even without operating cost saving. This is true when the lower operating cost of the refinery's own generating facilities does not provide an adequate return on investment. An adequate return to the refiner is usually the average rate of return on process investment. The conditions favoring an energy exchange include:

- A relatively large refinery output of unsalable material suitable for firing steam boilers.
- A relatively constant or recurring market condition which results in surplus residuals in order to satisfy the demand for distillates. Conditions can exist which make it possible to produce more salable middle distillates, if the residuals can be sold even at below current market prices. If the utility company will burn residuals without diluents or with less diluent than is ordinarily used in marketable fuel oils, more middle distillates will be available for sale.
- When a refinery producing large quantities of excess gas and residuals can burn the residuals in process furnaces and effect a profitable energy exchange with a public utility by exchanging the gas for steam and power.
- When the utility company is willing to bear a major share of the investment for transmission and distribution facilities.

Conditions Unfavorable to an Energy Exchange. Conditions which would not be favorable to an energy exchange include the following:

- None of the above conditions apply.
- The utility company has an abundant supply of very low cost energy, water power, natural gas from nearby wells, etc. With this energy source, the utility would be in a very favorable position to supply power and/or steam whether an energy exchange were effected or not.
- Refinery processes are "naturals" for recovering energy from waste heat at relatively low investment cost. This applies only when the waste heat could not be more effectively recovered with equal or lower investment by process equipment.
- Refinery residuals or the usual waste products can be used more profitably in other ways, or where long range market forecasts indicate a more attractive return for residuals or waste products than possible through the energy exchange.

Effect of Energy Exchange on the Refinery. When existing refineries increase steam and power generating facilities the investment cost of new equipment will vary greatly with the refinery's location, type of equipment, and the expense required to accommodate new equipment. The last mentioned factor may result in more investment for new installations in an old re-

finery than the cost of identical capacity in a grass roots refinery.

An energy exchange can be credited with investment cost savings of $4 to $8 per pound of rated capacity for field erected steam generating equipment. Package boiler installations may run $2 per pound lower in investment cost than field erected boilers. Investment costs for electric power generating plants range from $165 to $325 per kw of installed capacity. It is obvious that the cost of any sizable increment of steam or power generating capacity should be evaluated with the investment required to effect an energy exchange with a utility company.

Decreased Operating Expense. The operating cost savings, exclusive of fuel charges, that may be effected by the elimination of power and steam generating facilities normally range from 12-16 percent of the investment that would have been required for these facilities.

Fuel cost savings will vary with refinery location, operation, market conditions, and the availability of waste materials for boiler fuels. World-wide "booked" refinery fuel costs range from 5 cents to 80 cents per million Btu's with an average of approximately 25 cents per million Btu's. The methods of computing refinery fuel charges vary greatly with companies and within companies. Realistic fuel costs should be evaluated for each case under consideration for an energy exchange with a utility company.

Fuel Sales. An energy exchange often provides an opportunity for disposal of refinery waste products which would otherwise be unsalable. In some cases, disposal of such products is an additional expense to the refiner. Examples include excess refinery gas, cracked pitch and acid sludge. Very high viscosity residuals frequently can be heated and pumped to a utility company power plant adjacent to the refinery.

Effect on Process Operations. When high viscosity bottoms with a minimum of diluents can be delivered to the utility the quantity of available middle distillates may substantially increase. It is true that the same result might be achieved by burning in refinery furnaces if an equivalent quantity of bottoms were used.

Reliability of Service. When an energy exchange is attractive to the utility company it may be possible to arrange transmission and distribution schemes for steam and power with most of the investment for the utility company's account. In such cases it may be possible to provide a greater service reliability for the refinery than would be economically justified under other circumstances.

Effect on Public Utility. The utility company's load factor (ratio of average load to maximum demand) is usually low compared with the load factor of the average refinery. Unit costs of power therefore bear a large portion of the fixed operating costs. When a steady load such as a petroleum refinery is acquired the load factor is increased and the fixed unit costs of power are lowered. A steady assured power load also permits continuous operation of turbine generating units at loads close to ratings. This practice results in lower turbine steam rates with consequent reduction in fuel used in making power.

Low Cost Power Production. A steam-power exchange for refinery fuel will permit reductions in the cost of power produced in addition to those mentioned above. The most significant cost reduction will probably be attributed to a lower average unit fuel price. Other substantial reductions will be achieved by the lower heat rate for the portion of electric power produced by refinery steam extracted from steam turbines. If the refinery steam cost is based on the heat content of the extracted steam the heat rate of the power produced by the extraction may be less than one-half of the best heat rate obtainable by full condensing turbines. Over-all reduction in power generation costs will be dependent upon the ratio of extracted steam to full condensing steam consumption.

Additional Operating Cost. There are some additional operating costs for the utility company. Among these are:

(1) Additional boiler feed water treating including chemicals, fixed cost and operating labor on equipment.

(2) Additional operating labor and maintenance costs due to the more complex extraction turbine, and the necessity for providing more than one boiler per turbine, pressure reducing valves, double steam headers and boiler fuel systems, all to insure reliability of steam supply.

Adjustment in Investment. If because of the energy exchange, refinery products are burned instead of coal the cost of coal storage and handling equipment will be eliminated. (In many locations this would not be a factor.) The cost of additional feed water treating and heating equipment, the incremental cost of automatic extraction turbines over full condensing turbines, and the cost of the additional facilities required for steam system reliability will result in a somewhat higher investment for the utility company than would be required for a typical utility plant.

PLANNING AN ENERGY EXCHANGE

What aspects should be studied by the refiner before he enters into an energy exchange agreement? The refiner should study the proposed terms of the contract and their economic effect both short range and long range, investment and operating economics of the proposed exchange, the need for refinery standby facilities, and finally, the details of the installation and operation under the proposed exchange.

Proposed Terms of Contract. The purpose of the energy exchange is not only to reduce refinery investment and operating costs, but to be mutually profitable to both parties. Therefore, the refiner must carefully study the short range and long range economics of the proposed

agreement. Some of the factors which must be established, in conjunction with the utility, are:

- The fuel specification—minimum quality of fuel acceptable to the utility.
- The exchange basis—Btu's of fuel per pound of steam and/or per kilowatt hour of electricity, also any arrangement on supply of raw or treated water required for boiler make-up.
- The pricing of fuel requirements above the exchange for steam and electricity, and the extent to which the utility is obligated to purchase.
- The price relationship between fuel purchased under the contract and other fuels such as coal or gas, and the effect of changes in parity on the contract.
- Contract maximums—the quantities of steam and electricity which the utility is committed to supply and arrangements for increasing. The refiner must have a sound basis for determining his maximum electrical demand, his required steam pressure levels and the demand at each level.
- Basis for charges—this provides essentially a guaranteed return to the utility on its additional investment and provides the refiner a share of the saving resulting from the utility's more efficient operating cycle.
- Term of the contract, extensions, billing arrangements, protection for both parties against forces beyond their control, and provisions for cancellation.

Investment and Operating Economics. The refiner should compare his investment and operating economics under the energy exchange against either his independent generation of both steam and power or a purchase power-independent steam generation combination.

The economic studies should be made for both the short-range and long-range situations. Short-range may be considered to cover up to three years after initial operation; long-range, ten years after initial operation. The investment charged to the energy exchange should be the net investment—that is, the cost of the installation less any credit for facilities which the refiner would have to install if the exchange were not in operation. Such credits would be the cost of additional generation facilities or cost of replacement of obsolete facilities.

The annual savings under the energy exchange should also be estimated. These savings include operating cost savings such as in manpower, materials and supplies other than fuel, and reduction in overhead. The energy exchange should be credited with any profits resulting from upgrading of products including those which were used for fuel, and from disposal, under the energy exchange, of formerly unsalable products. Debits to the annual savings are the cost of the steam and electricity obtained from the utility, and the operating costs of the facilities.

Determination of the net investment and annual savings will permit calculation of the rate of return on the investment. However, the rate of return is not the only factor which the refiner should consider. He must also consider whether his independent generation, while in itself justified, will cost his company the loss of additional profitable fuel sales to the public utility. Also, will his generation produce a satisfactory rate of return both short and long range when compared with an equivalent investment in processing facilities? Will his tax situation be adversely affected? This can be the case in some overseas locations where electrical energy is supplied solely through government agencies. These are some of the aspects which must be considered in deciding whether or not a refinery should enter an energy exchange agreement.

Need for Standby Facilities. When the refiner considers an energy exchange, he seeks steam and power system reliability equal to that he would obtain with his own facilities. He should assure himself of the following:

1. That the public utility experience record of serious steam and power outages is satisfactory.
2. That outages of both steam and power are not likely to occur simultaneously.

If these two conditions are met, then the refiner need provide only the normal standby facilities required to permit safe shutdown of process equipment if a prolonged outage does occur. The facilities should permit shutdown without damage to equipment or hazard to personnel, and are the same regardless of the refinery source of steam and power.

If the refiner decides that additional standby facilities are needed, he should assess carefully the capabilities of such facilities. This will insure that his reliance on these facilities is well-founded.

Installation and Operation. The refiner must work out, in conjunction with the utility, the engineering and installation details and the division of responsibility of the exchange facilities. Of primary importance in this engineering will be insuring the reliability and adequacy of the supply to both the refiner and the utility. Some of these details are:

1. Number, voltage, capacity, and arrangement of electrical feeders to the refinery.
2. Number and size of interconnecting steam and fuel lines (water lines also if included in the exchange).
3. Size and location of fuel storage.
4. Method of metering and location of these facilities.
5. Coordination of refinery and utility electrical system protective relaying.
6. Provision for boiler make-up water.

In addition, the details of operations under the exchange should be studied. This will cover maintenance of any common facilities, emergency procedures, procedures for notification of plant shutdown, etc.

An example of one refiner's experience with an energy exchange can be found in the Esso Bayway-Public Service exchange.

Terms of the Energy Exchange. The agreement between Esso and Public Service can be segregated into three distinct parts. These are:

1. Exchange of fuel and water for process steam.
2. Purchase of electric power.
3. Sales of high viscosity and No. 6 fuel over that quantity exchange for steam.

The underlying principle of the agreement reflects the desire of both utility and refinery for an economic use of their invested capital. The ef-

fects of this principle are evident in the agreement for exchange of fuel and water for process steam.

Exchange of Fuel and Water for Steam. The contract requires that Esso pay a fixed charge to Public Service every month, regardless of the quantity of team taken by the refinery. The fixed charge is estimated to be that required to cover depreciation and provide an adequate return on Public Service's investment in facilities over and above those required for a conventional generating station of the same capacity. The economics accruing from extraction generation as opposed to condensing generation are passed back to the refinery in terms of credits against the fixed charge. These credits are proportional to the quantity of steam taken by the refinery. A minor "quantity charge" is made to the refinery which is also proportional to the quantity of steam taken.

In addition to the above payments for steam. Bayway is obliged to provide Public Service with a fixed quantity of fuel per pound of steam taken, and the reservoir or city water required to generate the steam.

The only restriction on the viscosity of the high viscosity fuel sent to Public Service is that it be pumpable and burnable in the refinery's own large process furnaces. Esso is free to supply No. 6 fuel oil in addition to or in lieu of high viscosity fuel.

Maximum pressures and temperatures of steam are established above which Public Service is not obliged to operate. Maximum allowable refiner demand for steam is established by the contract. Steam may be taken exceeding the stipulated maximum demand, but Bayway can be penalized for the excess demand depending on how it affects Public Service's operation.

Purchase of Electric Power. Electric power is purchased under the filed tariff of the utility, the transaction being segregated from the agreement on steam, fuel and water exchange. Power is purchased by Bayway at the standard commercial rate for the type of service used.

Operations Under the Contract. Operation under the agreement began in September, 1957. The contract duration is 20 years. Over the period that it has been in effect, both parties have found the arrangement satisfactory. Public Service has successfully handled high viscosity fuel from the refinery.

Supply of steam and power to the refinery has proved reliable. No serious outages have occurred. Bayway has shut down completely its steam and power generation facilities. It has found no need for maintaining standby equipment.

With the current electric power commercial rate structure having a demand and an energy charge, considerable incentive exists to keep the electrical load factor as high as possible. This same incentive would exist if the refinery were generating its own power. Since the demand charge under commercial power rates varies from month to month, based on the actual load imposed on the utility, there is more leeway in operations than with refinery generation. With the latter, a peak demand occuring at any time during the year requires adequate installed capacity to meet this peak demand.

Originally presented as "Joint Refinery-Utility Installations for Electric Power, Steam and Fuel Exchange" before the API Div. of Refining meeting, New York, May 29, 1959. ##

More About Electric Power

Long Term Electric Planning Pays. It is the intent of this paper to show how long-term planning can stretch investment dollars when installing new facilities and expanding or modernizing existing electrical distribution systems. The rapid growth in the use of electric power for oil refining justifies such long-range planning to insure maximum savings and still cope with the increasingly stringent energy requirements for modern processing units. This trend will continue as crude-oil runs increase and the fractions of each barrel are handled more times for produce upgrading. Heat and power needs amount to ap-

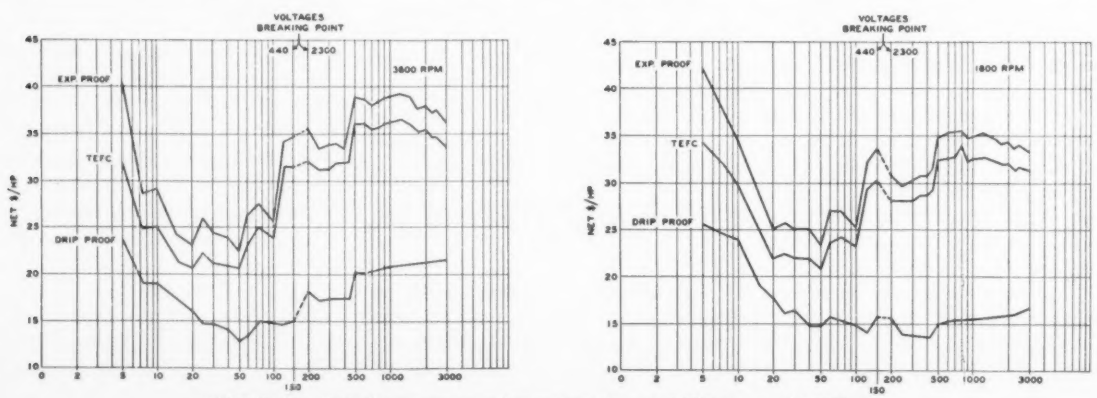


FIGURE 1—Relative motor costs for various sizes at 3,600 rpm and 1,800 rpm.

proximately one-third of the "cost of refining" crude oil. There is room for economy.

The distribution system offers one of the greatest opportunities for savings. Economic factors include the selecting of proper voltage levels, location of load centers, and adequate switchgear installations so that future growth is not hamstrung. A careful plan indicating the nature and timing of future expansions will help avoid the costly shortsightedness so evident when growth studies of existing installations are made.

Socony analyzed the capital costs for seven refineries using purchased electric power (see Table 1). All these plants use motor drives extensively. Two plants are "grass roots refineries" recently built for affiliated companies. In these, the cost of process units equaled the cost of plant facilities outside unit boundaries. However, when the replacement cost of five older Mobil refineries was analyzed, process units were found to be worth nearly one-third more than off-plot installations; the ratio is 57:43. The higher ratio apparently reflects a continued year-to-year capital improvement program whose emphasis is on processing. It is interesting that, while electrical facilities in the two new plants cost 10 percent of all installations outside process areas, electrical systems make up only 5.2 percent of off-plot costs in the older plants. Power used in the newer refineries averages about 4.1 kwh per bbl of crude oil, in the older refineries 3.6 kwh per bbl, so use of power does not explain the cost difference. The conclusion seems clear—proper planning of electrical distribution systems has allowed expansion and modernization of process facilities in particular, with very modest expansion of the plant electrical systems.

("Planning Economical Refinery Electric Power Distribution," K. N. Thompson, Socony Mobil Oil Co., Inc., New York, N. Y.)

TABLE 1—Comparing New and Older (Expanded) Refineries Shows How Capacity Increases Reduce Relative Cost of Electrical Distribution Systems

	Two Recent Refineries (Investment Basis)	Five Older Plants (Replacement Cost Basis)
Process units vs. "offsites" (all other) costs	50:50	57:43
Electrical costs "offsites" as percent all "offsites"	10 percent	5.2 percent
Electricity (all purchased), kwh per bbl of crude oil	4.1 approximately	3.6

Purchased Power Saves $200,000: This paper covers the increase in electric power load from 1948 to 1958 and outlines how electrical substations were increased from a load of 1,200 kva to the new load of 38,000 kva. This coincides with the increase of crude-oil runs and points out that each time the refinery electrical system was expanded it was done with a minimum of dollars. It outlines the close cooperation between the Ohio Power Company and Sohio which resulted in maximum reliability at minimum cost. Working closely with the power company we were able to attain a low kilowatt-hour cost.

("Purchased power saves $200,000 for Sohio," R. W. Mills, The Standard Oil Co. (Ohio), Cleveland.)

Motor Life Expectancy Up. Recent changes in the design of electric motors have increased their life expectancy and have improved their general resistance to environmental attack. Of particular importance to the refining industry are innovations in stator insulation systems and protective motor enclosures. Coupled with the hazardous area classifications outlined in API Standard RP 500, these developments have increased the outdoor application of motors which have a minimum of enclosure protection. The trend toward the use of more rugged insulation systems and away from expensive and elaborate motor enclosures should result in definite economies for the petroleum industry. Further developments needed to enhance the reliability and economy of electric motors in refinery service are improved bearings, improved insulation systems, and improved design for maintenance of clean heat transfer surfaces.

("Electric Motors In Petroleum Refineries," Lee B. Eddy, Universal Oil Products Co., Des Plaines, Ill.)

TABLE 1—Approximate Prices for Various Types of Squirrel-Cage Induction Motors Compared to the Price of an Equally Rated Dripproof Machine

Nominal Horsepower Rating	Dripproof*	TEFC	Explosion-proof	Weather Protected, Type I	Weather Protected, TypeII	Totally-Enclosed Forced-Ventilated*†	Totally-Enclosed Water-Air-Cooled*	Totally-Enclosed Water-Inert Gas-Cooled*
1,800 rpm								
2	1.0	1.3	1.6					
5	1.0	1.4	1.7					
25	1.0	1.4	1.6					
100	1.0	1.6	1.7					
200	1.0	1.8	2.0					
300	1.0	2.1	2.2	1.02	1.5	2.1	2.4	3.9
500	1.0	2.2	2.3	1.02	1.4	1.7	2.1	2.9
1,000	1.0	2.1	2.3	1.02	1.3	1.5	1.6	2.0
2,500	1.0	2.0	2.1	1.02	1.2	1.4	1.3	1.5
5,000	1.0	..	..	1.02	1.2	1.2	1.2	1.3
3,600 rpm								
2	1.0	1.4	1.7					
5	1.0	1.4	1.7					
25	1.0	1.5	1.7					
100	1.0	1.6	1.8					
200	1.0	1.7	1.9					
300	1.0	1.8	1.9	1.02	1.4	1.8	2.2	3.2
500	1.0	1.8	1.9	1.02	1.3	1.5	1.8	2.4
1,000	1.0	1.8	1.9	1.02	1.2	1.4	1.5	1.8
2,500	1.0	1.6	1.7	1.02	1.1	1.2	1.2	1.4
5,000	..	..	..	1.02	1.1	1.2	1.1	1.2

* These motors normally have 1.15 service factor (15 percent load capability above their nominal horsepower rating).
† Includes price of mounted nonsparking fan, explosionproof fan motor and explosionproof starter for the fan motor.
Note: Some motors equipped with the new insulation systems may be priced in the order of 15 percent greater than the values indicated above.

New API Installation Guide

A MANUAL of recommended practices for the installation of instruments in petroleum refineries is soon to be published by API. This manual results from work of the Subcommittee on Instruments of the API Committee on Refinery Equipment. A brief history of the development of the manual and a resume of its contents is presented. The manual is intended to serve as a guide for the installation of the generally used measuring and controlling instruments and related accessories in order to achieve safe, continuous, accurate, and efficient operation with minimum maintenance. The manual is to be published during late 1959 or early 1960.

("Refinery Instrumentation—A New Installation Guide by the American Petroleum Institute," R. R. Proctor, The Pure Oil Co., Crystal Lake, Ill.)

Level Control by Capacity: Instruments for measuring electrical capacity can be simple, reliable, and versatile. A system is described which uses the same electronic units for a variety of applications. A rugged transmitter is mounted near the point of measurement. The remainder of the circuit with the zero and span adjustments may be mounted in a convenient location. The system is independent of characteristics of the cable joining the two units.

The system is in use in Sun Oil Company refineries for level measurement or control of hot liquids, granular materials, very cold liquids, and corrosive liquids under difficult conditions where the absence of moving parts is advantageous. Compensation for effects of temperature change is included. The same system also is used for certain stream analysis applications. It is used to measure moisture in liquid hydrocarbon streams in the parts-per-million range.

("Versatile Capacity Measuring System for Level Control and Stream Analysis," E. N. Shawhan, H. L. Bachoffer, J. Lerner, and J. R. Wright, Sun Oil Co., Newton Square, Penn.)

Systems Engineering for Process Control: The usefulness of the systems engineering approach in solving an important process control problem in fluid catalytic cracking is shown. To meet the objectives sought for in an improved version of fluid catalytic cracking, a new concept of reactor temperature control was proposed. The proposed scheme was so unlike existing schemes that its performance could not be predicted from past experience alone. There was a clear need for a systematic evaluation of the control scheme.

A mathematical model of the reactor temperature control loop was devised and analyzed using standard techniques of servomechanism theory. The analysis indicated that the system would be stable and would respond adequately to wide ranges of operating changes. Observation of the initial unit operation showed the analysis to be correct in that the system proved to be safe, stable, and easily controllable. The discussion includes the derivation and solution of the mathematical model and interpretation of the results.

The report concludes with a generalized discussion of the value of the systems engineering approach for solving process control problems. As the need grows for a more quantitative understanding of process control systems, there will be a parallel growth of the systems engineering approach to solve the problems generated.

("Application of Systems Engineering to a Process Control Problem in Fluid Catalytic Cracking," R. E. Hall, Esso Research and Engineering Co., Linden, New Jersey and G. K. Tucker, Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.)

Computers. An analog computer has been designed, built, and operated to control a commercial distillation column to capacity vapor rate. It computes the actual vapor rate from measured reflux and product rates, the vapor capacity as a function of measured pressure, and finally the percent of vapor capacity actually utilized as a quotient. The finally computed percentage is recorded and can be used to control the tower to any desired percentage of capacity.

("Analog Computer—Controller for Capacity Control of a Distillation Column," R. L. Martin, W. O. Webber, Humble Oil & Refining Co., Baytown, Texas; J. F. Pink, Southwestern Industrial Electronics Co., Houston, and J. T. Hargett, Texas Instruments, Houston.)

The Human Side of Industry

EVERY DAY it is becoming more clear that in order to develop the human aspect of industry—managerial, white collar or blue collar—organizations will have to resort to more than formal programs and classroom courses. This paper deals with that task and places particular emphasis on managerial development. Special attention is devoted to the internal organization environment and to the idea of "management by objective and self-control." as a most useful method. (The Human side of Enterprise, Douglas McGregor, Massachusetts Institute of Technology, Boston.)

Process Operations Raise Safety Problems

THE SAFETY ASPECTS of process operations affect nearly everyone: the employe and his personal safety, the company and its investment, the general public and its well-being. Therefore, it is important that the process operator be familiar with the safety problems which concern him. Forums on safety provide a medium of interchange of information between refiners on such problems, and serve as a means of communicating information on unusual happenings in process operations. (Safety in Process Operations, John J. Coates, Esso Standard Oil Co., Pittsburgh.)

Seven Types of Protective Facilities. There are seven classes of basic protective facilities commonly installed in refinery process units as a protection against the hazards of fire or other emergencies. Here is a review of the controversial considerations which occur in the selection and design of such facilities, and suggestions as to the relative value of each system. The seven protective devices discussed are:

1. Pressure-relieving facilities
2. Vapor-depressuring systems
3. Liquid dropout or blowdown facilities
4. Firewater systems
5. Water-spray and fog systems
6. Structural fireproofing
7. Miscellaneous auxiliary facilities.

(Protective Facilities for Refinery Process Units, William C. Bluhm, Shell Oil Co., New York.)

Safety Programs Pay Off. Here are three different safety programs used by American Oil to develop safe operating procedures. Two were at the Texas City refinery, the third was company-wide. The first consisted of various refinery technical personnel reviewing and recommending changes to facilities. The second program utilized top level operators and supervisors in the Operating department in a discussion type session to prepare answers to about 600 questions on safe operating procedure.

The third plan was a review and study of various operations in the different refineries and was handled somewhat like plan one. It is believed the good results were obtained by having the people who control the particular operation do the talking and those who are to make use of the information, assist in developing the data. (Development of Safe Procedures, R. C. Steinhoff, Jr., American Oil Co., Texas City.)

More Than Standard Procedures. Use of standard procedures for startup, shutdown and emergencies comprise only 2 percent of the total operating time of a unit. The remaining 98 percent of the time spent in normal operations should be effectively used in developing desirable traits in the operators. Planned procedures and operating manuals help in this procedure but can hardly accomplish all desired results as we are dealing with human characteristics.

Here is an organization which employs a team effort based upon experience to maintain high standards of performance on a day-to-day basis. This involves a good outline of standard procedures and repeated daily efforts originating from diverse points. (Are Standard Procedures the Whole Answer? J. R. Howard, Texaco, Inc., Westville, N. J.)

A Decade of Progress

Motor Fuels: The trend toward fuels of improved quality for use in engines of increasing compression ratio and exhibiting improved efficiency characteristics has proven, thus far, to be sound. How much further this trend will continue will depend on the ability of the petroleum industry to supply fuels permitting these engines to operate satisfactorily on an economically justifiable basis.

A great deal of interest continues to be shown by the automotive industry in the use of gas-turbine and free-piston engines for automotive vehicle use. It is anticipated that developments along these lines will not materially influence the motor-fuel picture during the next decade. ("A Decade of Progress in Motor Fuels," W. J. Sweeney and J. F. Kunc, Esso Research and Engineering Co., Linden, N. J.)

Lubricants: New, multigrade oils reduce engine friction and allow 15-20 percent more gasoline mileage for short town trips and 5 percent more for over-the-road operation. Engines also produce about 5 percent more horsepower with the multigrade oils.

Improved lubricating oils have influenced the economy of our country. The oil-to-gasoline ratio has dropped from 1.8 percent to 1 percent over the past 10 years. Several fleets obtained 5 percent more gasoline mileage with multigrade oils.

Taxi engine overhaul periods were doubled by the use of heavy-duty oils, tripled by the use of highly compounded heavy-duty oils, and quadrupled by the use of the new polymeric detergent oils.

("A Decade of Progress in Motor Lubricant Technology," A. L. Lyman, California Research Corp., San Francisco, and F. W. Kavanaugh, California Research Corp., Richmond, Calif.)

Petrochemicals: Today, after years of unparalleled development, the petrochemical industry is running out of established markets before it runs out of cheap raw materials.

Nevertheless, the petrochemical industry will continue to be important to the refiner. He will continue to experience a steady demand for refinery gases by the petrochemical industry. This demand will grow at a rate commensurate with that being achieved by mature growth industries.

("A Decade of Progress in Petrochemicals," J. H. Forrester, Amoco Chemicals Corp., Chicago.)

Better, Faster Lab Results

ADVANCEMENTS in petroleum reforming technology have emphasized the need for rapid analyses to relate catalyst composition and structure to problems pertaining to process development and control. The techniques in general use for the determination of fluorides in catalytic materials are time consuming and cumbersome, and have represented a major obstacle for laboratories attempting to render services consistent with current demands.

Recent developments in pyrohydrolysis (elevated temperature steam hydrolysis) indicated a new approach to the problem, but did not provide a satisfactory solution because of cumbersome equipment and absence of sufficient heat to promote the reaction at a satisfactroy rate in the absence of accelerators. As a solution to the problem, the oxyhydrogen flame was investigated and found to provide the features necessary to convert the pyrohydrolytic technique to a rapid, simple procedure—a technique requiring less than 5 min to separate fluorine from a catalyst and recover it in a form adaptable to any of the well-known chemical methods of analysis.

("Rapid Pyrohydrolytic Separation of Fluorides in Catalysts Using an Oxy-Hydrogen Burner," Hoel, D. C., Fanale, D. T., and Clark, R. O., Gulf Research & Development Co., Pittsburgh.)

C and H Analysis: Increasing demands for carbon and hydrogen analyses in this laboratory necessitated a search for a faster and more accurate method than the conventional semimicro gravimetric method used for several years. The manometric method described has adequately fulfilled our requirements. Carbon dioxide and water from combustion of an organic material are selectively vaporized into an evacuated manometer and the pressure of each is measured. The carbon and hydrogen contents are calculated from the observed pressure values and calibration data.

Results by this semimicro manometric method are considerably more accurate, and analyses can be accomplished in one-half to one-third the time.

("Rapid Semimicro Manometric Method for Determination of Carbon and Hydrogen in Organic Compounds," Scott, R. L., Puckett, J. E., Price, H. A., Grimes, M. D., and Heinrich, B. J., Phillips Petroleum Co., Bartlesville, Okla.)

Phosphorus in Gasoline: Ethyl Corporation has developed two methods for determining phosphorus in gasoline accurately and rapidly. The first method is based on the formation of an intensely colored blue complex. The intensity of the color can be measured and used to calculate the phosphorus concentration. The second method uses the emmission spectrograph. Arsenic is added to the gasoline sample and the mixture is burned in a high-voltage electric discharge. Phosphorus is determined by measuring the ratio of light emitted by phosphorus to that emitted by arsenic.

The colorimetric method can be used for any type of gasoline sample containing phosphorus. It is used when the highest accuracy is required. The elapsed time for a single sample is approximately one hour. The spectrographic method requires 30 min. and is preferred because of its speed.

("Rapid Determination of Phosphorus in Gasoline—Spectrographic and Colorimetric Methods," Griffing, M. E., Leacock, C. T., O'Neill, W. R., Rozek, A. L., and Smith, G. W., Ethyl Corp., Detroit, Michigan.)

Faster Lab Results. One Socony laboratory has organized its work so that fast, as well as accurate, results are obtained. Conduct of this work represents a difficult administrative and organizational problem.

("Getting Faster Analytical Results from a Petroleum Laboratory," Childs, E. B., Wiberley, J. S., and Rather, J. B., Jr., Socony Mobil Oil Co., Inc., Brooklyn, N. Y.)

Platinum. Analysis of reforming catalyst must determine 0.006 percent of platinum on alumina, which is one percent. This new method entails the dissolution of the platinum and converting it into a colored compound. By measuring the intensity of the color produced with a highly sensitive instrument, it is possible to achieve the required accuracy.

("Assay Procedure for Platinum in Reforming Catalysts," Maziekien, Iris, Ermanis, Lucia and Walsh, T. J., Engelhard Industries, Inc., Newark, N. J.)

Lube Oils: Six methods have been compared for obtaining carbon-type composition, that is, percent of carbon atoms in paraffinic structure, percent of carbon atoms in naphthene structures, and percent of carbon atoms in aromatic structures.

These methods have previously been shown to give comparable results in the analysis of oil fractions. The present study applies the six methods to the data for pure compounds synthesized by API Project 42.

Since these correlations are a statistical representaiton of the composition of petroleum fractions, it is of interest to see how well these methods agree with composition data for pure hydrocarbons whose molecular weights lie within the range encountered in the lubricant portion of petroleum.

Each of these physical-property correlations has been applied to as many as possible of the API 42 hydrocarbons for which sufficient data has been published. The differences between the actual carbon-type composition, and that predicted from the physical properties by the correlations were grouped by hydrocarbon class and evaluated statistically. The statistical data indicate that the correlations, at present available, for determining the carbon type composition of lubricating oil, in general, show satisfactory agreement with data for pure compounds.

("Significance of Pure Compound Data in Relation to the Carbon-Type Analysis of Lubricating Oil," King, R. W., Kust, M. A., and Kurtz, S. S., Jr., Sun Oil Co., Marcus Hook, Pa.)

Catalyst Check: The carbon-to-hydrogen ratio of coke deposited on the catalyst is a very useful measure of stripping efficiency and of air requirements during air regeneration. The present analytical method is designed to measure both the carbon and hydrogen contents of the coke. It is particularly useful for samples of low hydrogen content—catalyst samples containing as little as 0.002 percent by weight of hydrogen have been analyzed. Adsorbed water on the catalyst has no effect. The method is easily adapted to route analyses. Twelve complete analyses can be made in an 8-hour day.

("Manometric Determination of Carbon and Hydrogen Content of Cracking Catalyst," Longman, R. T., Hiett, T. A., Murphy, J. L., Robinson, J. L., Shell Oil Co., Houston, Texas.)

Research Takes Stock

TO BETTER evaluate the return on the API investment in fundamental research on the properties of hydrocarbons and related materials, this activity is examined by the use of the format of the balance sheet and the financial annual report. The status of the fundamental research is reviewed from the standpoint of the nature of the accumulated assets to date and of the present liabilities, or what we still owe to petroleum science.

("The API Balance Sheet on Properties of Hydrocarbons," Kuhn, W. E., The Texas Co., Beacon, N. Y.)

Crude Oil. Keys to understanding crude oil have resulted from a fundamental research study of sulfur compounds. For example, thermal instability of sulfur compounds suggests a low-temperature history; the presence of mercaptans and chain sulfides, but no simple thiophenes, in Wasson, Texas, crude oil is the exact converse of the facts regarding Wilmington, Calif., crude oil; quantitative trends indicate the disappearance of mercaptans and chain sulfides at about 8 to 10 carbon atoms, even in Wasson crude oil; alkyl cyclic sulfides increase concomitantly with the disappearance of the chain sulfides; the fact that most of the cyclic sulfides are 5- or 6-membered, fully hydrogenerated rings; the presence of complex sulfides, such as thiaadamantane; the fact that benzothiophenes and polybenzothiophenes appear to constitute the greater portion of sulfur compounds in crude oil, even in an oil such as Wasson; the presence of elemental sulfur in a few crude oils; the fact that none of the sulfur compounds determined thus far are in thermodynamic equilibrium. All of these are keys, but, in some instances, the locks they fit have not been found.

("Keys to the Mystery of Crude Oil," Smith, H. M., Dunning, H. N., Rall, H. T., Ball, J. S., U. S. Department of the Interior, Bureau of Mines.)

Geophysics: The American Petroleum Institute recognized the need for increased fundamental research in geophysics and recently began supporting research in universities, principally in fundamental studies of elastic wave propagation. This field of study is pertinent to seismic exploration, the most definitive and most costly of present geophysical methods.

("Geophysical Research and the American Petroleum Institute," O'Donnell, T. J., Gulf Research & Development Co., Pittsburgh, Pa.)

Weather Expectancy: The operational use of weather forecasts has remained an intuitive art because it is difficult to interpret the usually indefinite information presented. The forecaster's expectations are always somewhat uncertain, and the language of forecasts seldom reflects precisely what is likely to happen. There are two main avenues to improve this unsatisfactory situation through fundamental research—first, by statistical study to develop accurate means of stating forecast probabilities for the events which may occur, second, by employing principles of physical and synoptic meteorology to analyze and pinpoint more definitely the most probable course of events.

The American Petroleum Institute's Advisory Committee on Fundamental Research on Weather Forecasting has followed both of these avenues in attacking two specific forecasting problems of vital concern to the petroleum industry:

1. The estimation of unusually warm or cold weather (degree-day departures from normal) a month or more in advance for stations in the United States.
2. The course of development of hurricanes from small disturbances in the Gulf of Mexico, several days in advance.

("Weather Expectancy—Science or Clairvoyance?" Roop, F. C., Standard Oil Co. (Indiana), Whiting, Ind.) ##

5th WORLD PETROLEUM CONGRESS

Now—Dibasic Acids by Direct Oxidation

New catalytic liquid-phase air oxidation process produces polycarboxylic acids directly from mixed alkyl aromatics

D. E. Burney, G. H. Weisemann and Nathan Fragen
Standard Oil Company (Indiana)
Whiting, Ind.

EACH OF THE THREE AROMATIC ACIDS—phthalic, isophthalic and terephthalic—has been made by direct oxidation of the individual isomeric xylenes. However, a new single process has been developed and placed in commercial operation for preparing these acids from mixed alkyl aromatics.

Nature of the Process. The new process is based on an original discovery of the Mid-Century Corporation, a former affiliate of the Scientific Design Company and now a wholly-owned subsidiary of the Standard Oil Company (Indiana). The process is a liquid-phase air oxidation involving a heavy metal and some form of bromine as catalyst. The heavy-metal component may be one or more of the variable-valence metals that have been used as oxidation catalysts—cobalt, manganese, and molybdenum, for example. These metals are preferably used in the form of salts that are soluble in the liquid phase under reaction conditions; naphthenates and acetates are satisfactory. The results obtained with representative materials in laboratory tests using *para*-xylene as feed are summarized in Table 1. These reactions were carried out in a batch reactor consisting of a vertical pipe one inch in diameter and three feet long attached to a condenser of the same dimensions. Air was bubbled through until essentially no more oxygen was taken up.

TABLE 1—Representative Heavy-Metal Components
(195-205 C, 400 psi, 2 hours, 150 grams Acetic Acid)

Metal Compound		NH_4Br	para-Xylene	Terephthalic Acid
(Name)	(grams)	(grams)	(grams)	(mole %)
Cobalt Acetate	1.0*	0.75	75	79
Manganese Acetate	1.0*	0.75	75	74
Ammonium Molybdate	1.0	0.75	75	74

*As the tetrahydrate.

Bromine may be introduced either as the free element or as a compound. Data taken from similar laboratory-scale *para*-xylene oxidations with representative bromine-containing materials and manganese acetate are summarized in Table 2. Both organic and inorganic forms are effective. Preferably, this component of the catalyst should yield a soluble form of bromine under reaction conditions.

TABLE 2—Representative Bromine-Containing Materials
(195-205 C, 400 psi, 1.5 Hours, 150 grams Acetic Acid)

Bromite Compound		Manganese Acetate	para-Xylene	Terephthalic Acid
(Name)	(grams)	(grams)	(grams)	(mole %)
Benzyl Bromide	1.0	1.0	75	67
Bromine	1.0	1.0	75	75
Ammonium Bromide	0.5	0.6	49	75
Potassium Bromate	1.0	1.0	75	80
Acetylene Tetrabromide	1.0	1.0	75	81

Bromine is unique in effectiveness as a catalyst component for air oxidation. None of the other halogens or their compounds approach it in activity.

A reaction medium or solvent other than the hydrocarbon being oxidized is not required, but often is useful. Many of the acid products are solids at reaction tem-

perature and, therefore, difficult to handle. A material that is liquid and stable under reaction conditions can serve as a transport medium for the products, can promote efficient contact with the air, and will enable complete conversion of the feed. Although it should dissolve the hydrocarbon and both catalyst components, it need not dissolve the product acids. Organic carboxylic acids are good solvents.

Reaction conditions differ with the hydrocarbon being oxidized. Reaction temperature is usually between 125 and 275 C. Pressure up to about 40 atmospheres may be required to maintain the liquid phase; it also assists in increasing the partial pressure of oxygen in the system. Reaction time for most alkyl aromatics is one-half to three hours.

Air is the cheapest source of the oxygen required, but gas mixtures containing more or less oxygen can be used. Figure 1 shows how oxygen from air is taken up in a typical oxidation of *para*-xylene with an efficient catalyst. Reaction starts as soon as air is introduced. The original slope of the curve reflects oxygen availability, rather than a chemically-controlled rate of oxidation; nitrogen containing little or no oxygen is evolved until the alkyl groups have been oxidized. Near the end of the oxidation, the air rate needs to be decreased to maintain the oxygen concentration below hazardous levels. Because the oxygen is utilized efficiently, 5 to 15 percent more than the theoretical amount is enough to give essentially complete conversion.

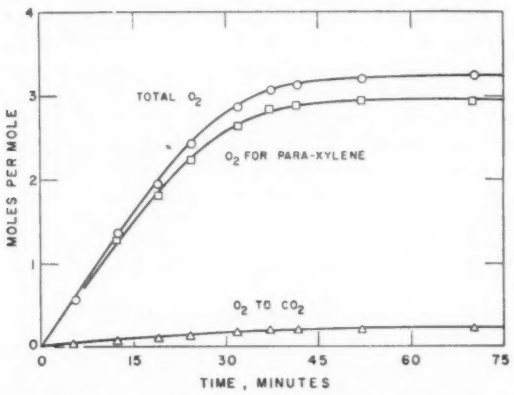


FIGURE 1—Shows how oxygen from air is taken up in a typical oxidation of *para*-xylene with an efficient catalyst.

The same process can be used for mixed xylene and for purified individual isomers. Oxidation can be carried out in a batch process or continuously. The steps involved in a typical batch process for the conversion of mixed xylenes to phthalic acids are shown in Figure 2. Here a reaction solvent is useful because the product acids are solids. Preheated solvent, xylene, and catalyst solution are charged, and air is passed through the reactor. Heat of reaction may be removed by cooling coils or by pressure control; the pressure on the system is so adjusted that the mixture refluxes at the desired reaction temperature. When the oxygen content of the evolved gas indicates completion of the reaction, the air flow is stopped and the pressure adjusted to atmospheric. Solid acids are separated from the solvent and catalyst by

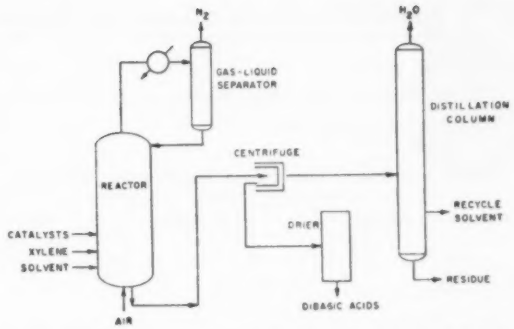


FIGURE 2—These steps are involved in a typical batch process for conversion of mixed xylenes to phthalic acids.

centrifuging; any type of filtration is equally satisfactory. The centrifuge cake is washed to remove adhering reaction solvent and then dried. The filtrate is distilled to remove water formed in the reaction and to purify the solvent for recycle. A small residue fraction from this distillation contains the catalyst components, small amounts of partially oxidized products, and benzoic acid if any toluene or ethylbenzene is present in the feed.

TABLE 3—Total Crude Product Distribution

Product	Yield (Mole %)
Terephthalic Acid	90.0
para-Toluic Acid	2.4
para-Methylobenzoic Acid	0.2
para-Aldehydobenzoic Acid	2.3
Unidentified	0.5
Carbon Dioxide	2.8
Recovery	98.2

In application of the process, conversion of the xylenes is typically greater than 95 percent, and the yield of phthalic acids is greater than 80 mol percent. The total crude product distribution from a representative laboratory *para*-xylene oxidation is shown in Table 3. In addition to the desired acid, small amounts of incompletely oxidized materials are present. Principal ones are the expected intermediates: methyl-, methylol-, and aldehydobenzoic acids. A little material of unknown composition is also present. Crude phthalic acids filtered from the reactor effluent are of high purity, as shown by neutral equivalents of 82.0 to 82.7, as compared with theoretical value of 83.0.

Versatility of the Process. Our method can be applied to convert most alkyl aromatics to acids with one or more carboxyl groups attached to the ring. The ring portion of the molecule is stable under oxidation conditions, so only side-chains are attacked. The effect of side-chain structure on oxidation is illustrated in Table 4. Methyl groups give the highest yields of carboxylic acids; other normal side-chains oxidize somewhat less readily. Secondary alkyls oxidize but give still lower yields. The tertiary group is more resistant to oxidation; conditions can be chosen either to leave it intact or to oxidize it to a carboxyl group. Thus, tertiary-alkyl aromatic acids can be made easily. In addition, the process can be controlled so that some but not all of the alkyl groups are converted to carboxylic acids; thus, alkyl dibasic acids can be made from trialkyl aromatics,

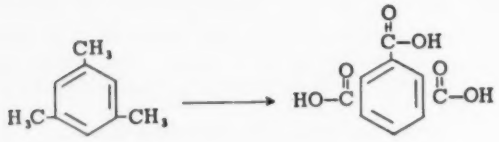
and dialkyl dibasic and alkyl tribasic acids can be made from tetraalkyl aromatics.

TABLE 4—Effect of Alkyl Group-Structure On Oxidation

Aromatic Hydrocarbon	Acid Products	Yield*
		(Mole %)
Toulene	Benzoic	88
Ethylbenzene	Benzoic	79
Cumene	Benzoic	57
para-t-Butyltoluene	t-Butyl Benzoic	87
1, 3, 5-t-Butylxlene	t-Butyl Isopthalic	82

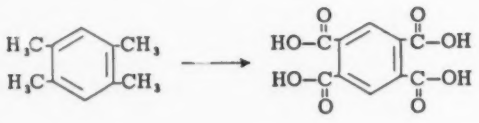
* Under the same reaction conditions.

Other alkyl aromatics that can be converted to carboxylic acids include mesitylene to trimesic acid,



pseudocumene to trimellitic acid,

and durene to pyromellitic acid.



Any products that contain acid groups *ortho* to each other can be dehydrated to anhydrides. Thus, trimellitic anhydride and pyromellitic dianhydride are readily obtained from the corresponding acids. Partially oxidized alkyl aromatics, such as toluic acids, toluic acid esters, and halomethyl and hydroxymethyl aromatics, are suitable starting materials. Halogen atoms attached to the ring are unaffected by the oxidation conditions and appear in the products. Mono-, di-, tri-, and tetrachloroxylenes can be converted to the corresponding chlorinated phthalic acids. Halogen atoms in the side-chains, instead of in the ring, are removed during the reaction.

The naphthalene nucleus, like the benzene nucleus, is stable in the process, so that napthhalene mono- and polycarboxylic acids can be made. The potential availability of polyalkylnaphthalenes from petroleum fractions suggests interesting future prospects for these acids. Heterocyclic compounds that contain alkyl-substituted aromatic-like rings yield the corresponding heterocyclic carboxylic acids. Thus, 3-methylpyridine is readily oxidized to nicotinic acid.

Present Commercial Status. Commercialization of this amazingly versatile process is well under way. Amoco Chemicals Corporation, chemical manufacturing and marketing subsidiary of the Standard Oil Company (Indiana), has built and is operating a commercial plant at Joliet, Illinois, in which petroleum-derived mixed xylenes are the raw material. The products are phthalic anhydride, isophthalic acid, terephthalic acid, and benzoic acid; plant capacity is 60 million pounds per year. The plant is flexible enough to meet changing market demands; product distribution can be controlled by varying the composition of the xylenes used or by charging the pure isomers. In an adjacent plant, some of the acids are converted to the corresponding dimethyl esters.

In September, 1958, trimellitic anhydride was made available in development quantities. It is made by oxidizing pseudocumene and dehydrating the trimellitic acid. The product shows promise as a raw material for the production of alkyd surface coatings of the water-soluble baking type. It also contributes increased hardness and faster drying properties to air-drying alkyd resins. It may be useful in ester plasticizers, in dyes, in unsaturated polyesters, as a curing agent for epoxy resins, and as a chemical intermediate.

Three companies have been licensed to build and operate plants to carry out the same oxidation process. Mitsui Petrochemicals Company has a plant in operation in Japan for oxidizing *para*-xylene to terephthalic acid. Imperial Chemical Industries is building a similar plant in England. Maruzen Oil Company also has a plant under construction in Japan. These plants will bring the total capacity for acid production by the new oxidation process to about 120 million pounds per year.

Original presentation was before the Fifth World Petroleum Congress, New York, May 30-June 5, 1959.

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5th WORLD PETROLEUM CONGRESS

New Route for Dicarboxylic Acids

Here's a new scheme for terephthalic and isophthalic acids, based on benzene and propylene, which gives high purity, fiber grade acids in predetermined quantities

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A NEW METHOD for the manufacture of terephthalic and isophthalic acid has been developed. It avoids the drawbacks attending the majority of other processes.[1,2] It starts with materials readily available in the petroleum industry and produces a very pure product.

This new process proceeds in two steps:

1. The production of *para*- and/or *meta*-diisopropylbenzene (*para*- and/or *meta*-DIPB) from benzene and propylene, using a new alkylation technique.

2. The production of terephthalic acid (TPA) and/or isophthalic acid (IPhA), both of high purity, from diisopropylbenzene by a selective catalytic oxidation in the liquid phase with air.

The difficulty of separating xylene isomers is circumvented by the use of DIPB, whose *para* and *meta* isomers can be separated by distillation. The alkylation step gives complete flexibility as regards the relative quantities of the *para* and *meta* isomers to be produced.

PREPARATION OF PARA- AND META-DIISOPROPYLBENZENE

The process for manufacturing pure *para*- and *meta*-diisopropylbenzenes hinges on two main points:

1. The *para* isomer can be separated from the other isomers by distillation (boiling points: 210.4 C. for *para;* 203.2 C. for *meta;* 203.8 C. for *ortho*).

2. The formation of *ortho*-diisopropylbenzene can be suppressed. This point is essential only for the preparation of the *meta* isomer, which cannot be separated from the *ortho* compound by distillation.

Chemistry of the Process. Benzene and cumene are possible starting materials for diisopropylbenzene manufacture, but the latter is to be preferred. With cumene, the reconversion of unwanted by-products may be incorporated into the reaction scheme more easily, as will be apparent later. Its alkylation with propylene yields a mixture of DIPB isomers and higher alkylated products, such as triisopropylbenzenes (TriIPB) and tetraisopropylbenzenes (TetraIPB).

To ensure a high yield on base materials, the unwanted higher alkylates have to be converted again into cumene, which can then be recycled to the alkylation step.

Dealkylation would be a possible way of doing this, but this reaction requires drastic conditions, giving rise to considerable losses by formation of useless by-products or even coke.

A much more elegant way to convert the polyisopropylbenzenes appeared to be their reaction with benzene. This so-called transalkylation is carried out under mild reaction conditions; the benzene acts as an aceptor of isopropyl groups and high yields are achieved. The reaction is accompanied by isomerization of the DIPB fraction.

Integration of the cumene alkylation with the transalkylation leads to a simplified reaction for the production of the *para*- and *meta*-diisopropylbenzenes as shown in Figure 1.

Process Variables

Base Materials. Best results are obtained with nitration grade benzene which has a low thiophene content. It may originate from any source. The propylene feed is available from normal refinery operations in the form of a propane-propylene stream. It should preferably contain not less than 40 percent of propylene.

Catalyst. For both the alkylation and the transalkylation use is made of a silica-alumina-type catalyst, such as used in conventional cracking operations, which for

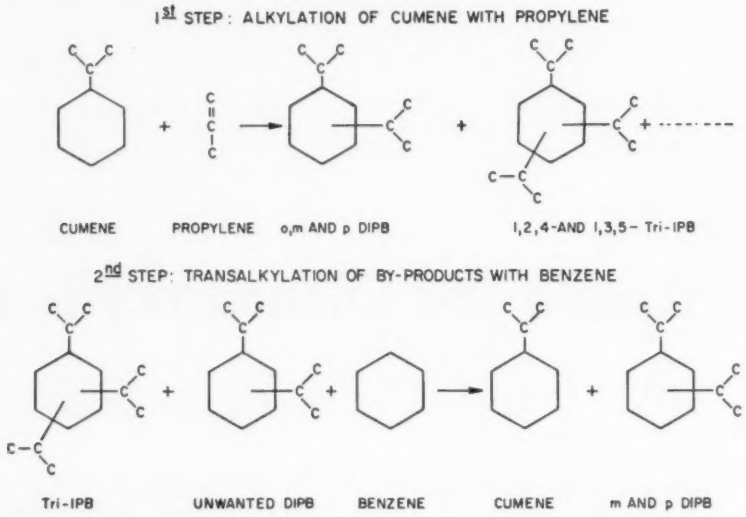

FIGURE 1—A simplified reaction is achieved by the integration of the cumene alkylation with a transalkylation step.

optimum results has to be pretreated. It fulfills the requirements of not yielding by-products which would interfere with the separation of the isopropylbenzenes and of producing a high proportion of the *para* isomer, which is still considered the most valuable one.

Choice of Reaction System. Carrying out the reaction in the vapor phase results in considerable fouling of the catalyst. A single-stage slurry process in a stirred tank reactor was therefore developed, which is used for the alkylation as well as for the transalkylation. The liquid-phase process is characterized by a low propylene concentration in the alkylation reactor, easy removal of heat reaction and the possibility of continuous refreshing of the catalyst.

Reaction Conditions. Reaction temperatures of 150-250 C. are used in the alkylation reaction. The lower temperatures favor high *para*-DIPB contents (under optimum conditions, as high as 55 percent of total DIPB), but in the higher temperature range, *ortho*-DIPB formation is very much reduced, which is important if pure *meta*-DIPB is to be obtained. The transalkylation temperature should be in the range of 240-320 C.

The reaction pressures are maintained at such levels that the reaction is carried out in the liquid phase. Reactant residence times, catalyst concentrations and consumptions in both reactors are adjusted for optimum reactor performance.

Two important reaction variables are the ratio of cumene to propylene in the alkylator feed stream and the ratio of propyl groups to aromatic rings present in the feed to the transalkylator. For an integrated process, these variables are directly related and Figure 2 shows the relationship for the case in which either *para*- or *meta*-DIPB is the sole product of the plant.

One might wonder whether two reactors are really essential. In principle a one-reactor system could be imagined, fed with benzene and propylene; after DIPB removal from the product stream, all other compounds could be recycled to the reactor. Such a system, however, has been shown to have a very low operational flexibility and the yields are lower than with the two-reactor systems, where the possibility of having different reaction conditions for essentially different processes is turned to full advantage.

Design and Operation of the Alkylation Pilot Plant. Although in principle alkylation reactions, like the one dealt with here are straight-forward processes, a pilot having a fairly large capacity (one-fourth ton per day) was built to:

1. Provide sufficient feedstock DIPB for the oxidation pilot plant;

2. Determine accurately the formation, the possible build-up and the equilibrium levels of certain by-products. Although these are formed in small quantities, they could well affect the alkylate yield—by necessitating certain bleed streams—and the oxidation performance, via the attainable DIPB purity;

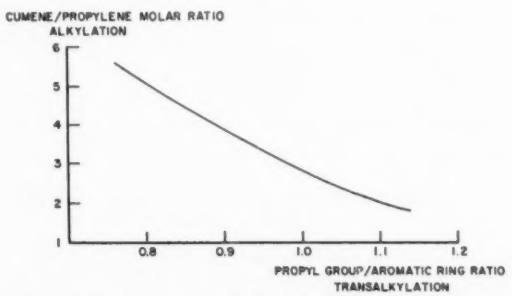

FIGURE 2—Shows the relationship between the cumene/propylene molar ratio in the alkylator and the propyl group/aromatic ring ratio in the transalkylator under integrated conditions.

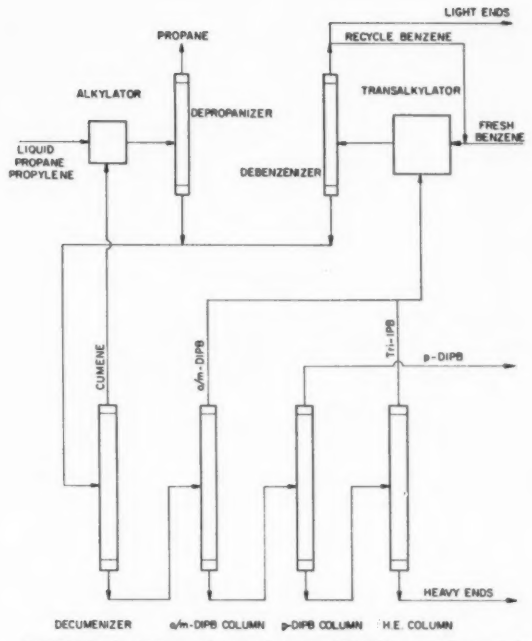

FIGURE 3—Flow scheme for para-DIPB manufacture in the alkylation pilot plant. Slight modifications are needed for meta-DIPB.

3. Confirm the reaction conditions established in the bench-scale experiments in long duration runs with full integration.

During the operation of the pilot plant, some additional aspects could be investigated, which would be useful for the design of a commercial plant. In this respect, the catalyst consumption, the influence of impurities in the raw materials, the control of the distillation section, etc.

A simplified flow scheme showing the manufacture of *para*-DIPB is given in Figure 3. The preparation of *meta*-DIPB only, requires slight modification in the reactor conditions and in the column line-up as compared with Figure 3, where *para*-DIPB is the sole product.

A number of integrated runs in this pilot plant fully confirmed previous bench-scale experiments. The molal yields of *para*- and/or *meta*-DIPB on benzene and propylene consumed are well above 90 percent. In the case of *para*-DIPB manufacture, some 2 percent light ends and some 5.5 percent heavy ends are produced, resulting in a *para*-DIPB yield of approximately 92.5 percent. Product purities are high. *Para*-DIPB can be produced with a purity of 99.5 percent; the *meta*-DIPB purity is slightly lower. The optimum catalyst refreshment rate is of the order of 1.0 percent on DIPB produced. Mild steel proved to be a perfectly suitable construction material for nearly the whole plant. Occasionally, e.g., for some of the reactor parts, type 316 or 321 stainless steel is recommended.

In conclusion it can be said that continuous production of *para*- and *meta*-DIPB in any predetermined ratio from benzene and propylene can be realized under fully integrated conditions with a two-reactor system. All information needed for a complete commercial design is immediately available.

PREPARATION OF TEREPHTHALIC AND ISOPHTHALIC ACIDS

The conversion of both isopropyl groups of the DIPB molecule into carboxyl groups can be carried out with nitric acid. This process is not very attractive, however, in view of the relatively great losses of nitric acid and on account of the product being contaminated by nitrocompounds. Therefore, the efforts were concentrated on air oxidation. An economically attractive process was worked out and fully developed on a pilot-plant scale.

Chemistry of the Process. Oxidation of alkyl benzenes with oxygen is known to occur by means of a free-radical chain mechanism. In the case of isopropyl benzenes, the first product is a relatively stable tertiary hydroperoxide. In the presence of catalysts, such as oil-soluble compounds of the transition metals, the hydroperoxide is decomposed into acetophenone and tertiary carbinol derivatives. Aromatic acids are hardly formed when cumenes are oxidized in this way.

However, it was found that the oxidation of isopropylbenzenes to form dicarboxylic acids does become possible if an organic acid meduim—preferably a lower fatty acid, such as acetic acid—and a metal catalyst are used. Air oxidation of para-diisopropylbenzene under these conditions leads to the formation of terephthalic acid.

The latter oxidation is the result of a concerted process in which several steps are to be distinguished. A fundamental study covering the various reactions involved revealed that the rate-determining step in the oxidation of diisopropylbenzene to dicarboxylic acid is the conversion of the intermediate isopropylbenzoic acid. An appreciable rate of conversion of this monobasic acid is only attained when free radicals are produced in the first stage of the oxidation of the diisopropylbenzene itself. A highly simplified scheme of the main reactions is given in Figure 4. Short-lived intermediates, such as hydroperoxides, and side reactions have been omitted.

Each step requires oxygen and a specific metal catalyst, while the conversion of keto groups into carboxylic groups must be carried out in a fatty acid medium. Since in a continuous process, the relative concentrations of DIPB and intermediates establish themselves on a level inversely proportional to the reaction rates, a steady-state reaction mixture will contain mainly monobasic acid, a smaller concentration of DIPB and only minor amounts of the other intermediates. The end product TPA or IPhA has a low solubility in the mixture; it crystallizes and is recovered by filtration.

Process Variables. Early batch and semi-continuous experiments in the laboratory, followed by further process development work carried out in a small continuous bench-scale unit with a tubular reactor of 1½ gallons capacity, provided the following information on process variables.

Catalysts. Soluble salts of the transition metals are well-known catalysts for liquid-phase oxidations. A highly specific catalyst is needed in this case in order to perform the complicated sequence of reaction and produce the dicarboxylic acid in a high yield. A mixture of cobalt and manganese acetate was found to give

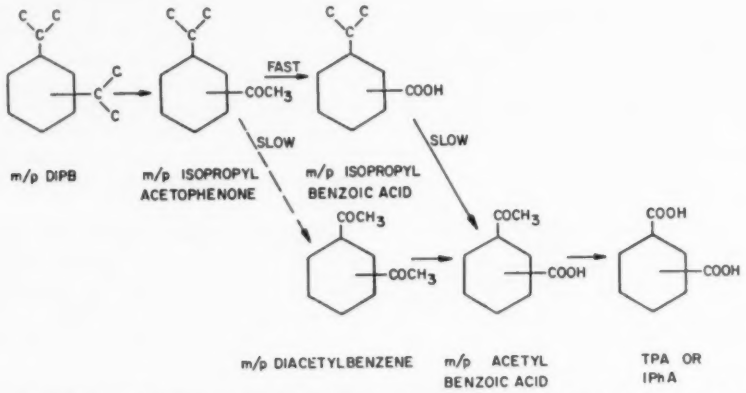

FIGURE 4—The rate-determining step in the oxidation reaction is the conversion of the intermediate isopropylbenzoic acid.

optimum results with regard to both yield of the high-purity acids and rate of reaction. Variation of the organic anion of the catalyst had no effect on the overall reaction. In the acetic acid medium, therefore, the metal acetates were the catalysts preferred.

Choice of Reaction System. The reaction is carried out in a liquid acetic acid medium in which catalysts and intermediates are soluble. DIPB is fed into the reactor continuously while air is blown through. The oxidation being highly exothermic, a considerable heat of reaction has to be removed. It was found that this should be effected by evaporation of the acetic acid solvent rather than by surface cooling in view of rapid fouling of the cooling surfaces. An excess of air over the amount theoretically needed for oxidation of DIPB is used, thus enabling the temperature to be controlled by varying the air flow rate. By feeding the air through nozzles at the reactor base, the reactants are adequately mixed while the oxygen is sufficiently dispersed. The product TPA or IPhA crystallizes from the reaction medium and is continuously removed.

Reaction Conditions and Concentration of Reactants. A temperature range of 120-150 C. gives the best results as to product yield and rate of reaction. Pressures of 2-8 atmospheres are applied depending on the temperature and air flow rate used.

Increasing the catalyst concentrations has been found to improve the dicarboxylic acid yield. A limit is set, however, by the solubility of the catalyst in the reaction mixture, which depends mainly on the water and formic acid concentrations in the liquid phase. Formic acid precipitates the catalyst, but the effect can be counterbalanced by raising the water concentration.

The rate of reaction is proportional to the concentration of intermediates in the reaction mixture, but at higher product purity is unfavorably affected. Operation at about 30 percent intermediate concentration in the liquid phase appears to be practicable.

Certain metal ions in solution have a detrimental effect on the dicarboxylic acid yield. Especially the iron concentration in the reaction mixture should not exceed 50 ppm.

The overhead gas consists of the excess air, acetic acid and by-products of the oxidation. In a three-column distillation system, a separation is effected between gases (i.e. CO_2, CO and formaldehyde), water, formic acid and acetic acid. The latter is recycled to the reactor after part of it has been used for washing the crystalline product.

Design and Operation of the Oxidation Pilot Plant. A one-fourth ton/day oxidation pilot plant design was constructed with the following aims:

1. To confirm or improve the reaction conditions derived from the bench-scale studies;
2. To establish the influence of DIPB feed purity on by-product formation and therefore ultimately on product purity and yield;
3. To study the performance of construction from the point of view of both mechanical resistance to corrosive conditions and yield losses due to contamination of the reaction medium with unwanted trace materials;
4. To study the scaling up of some major equipment items, such as the oxidation reactor, to their commercial sizes;
5. To provide large quantities of the acids for product evaluation purposes.

Operation of the pilot plant started in April 1957 and TPA and IPhA were manufactured on a continuous basis until June 1958. A simplified flow scheme showing the manufacture of TPA or IPhA is given in Figure 5.

The main sections of the plant are the reactor, the distillation section in which the reactor overhead vapour stream is separated into its components and the phthalic acid recovery section.

In a variation of the process, the formic acid, instead of being distilled off, is removed from the overhead vapour stream by selective catalytic decomposition; acetic acid and water are then separated by distillation. This simplifies the process considerably, but naturally involves losing the netback for pure formic acid.

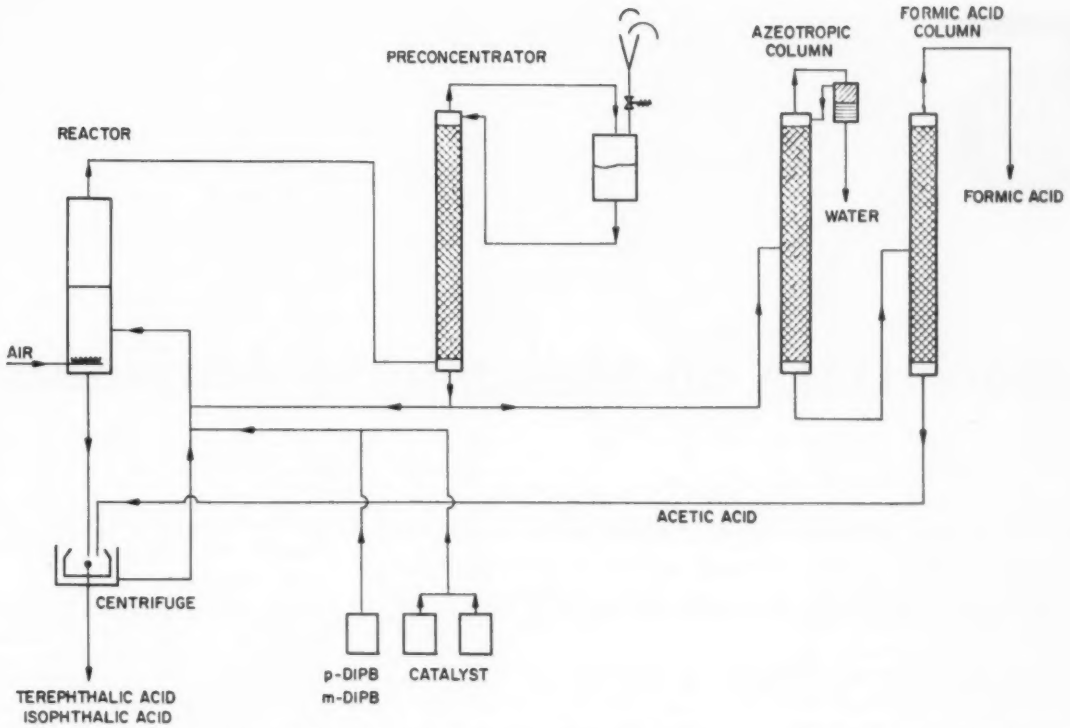

FIGURE 5—In this oxidation pilot plant flow scheme cooling is accomplished by evaporation of the acetic acid solvent.

In the choice of construction materials, low maintenance at the severe corrosive conditions encountered was the main criterion. Contamination by metal ions was avoided by deionizing the reactor recycle streams by means of ion exchange. Where this could not be done, owing to the presence of the valuable catalyst ions, the choice of construction materials was dictated by the necessity to avoid harmful metals at any price.

During a number of long-duration runs, all the objects mentioned in the preceding paragraph were achieved. In general, the results confirmed the bench-scale experiments and conclusively showed that it is possible to produce, on a continuous basis and under fully integrated conditions, TPA and IPhA from *para*-and *meta*-DIPB by air oxidation in the liquid phase. Molal yields as high as 85 percent of TPA and IphA on converted DIPB were obtained, while TPA and IPhA purities better than 98.5 percent could be attained. Catalyst refreshment rates are negligible.

As a result of these pilot plant tests, all information needed for a complete commercial design including special points, such as reactor design and control and materials of construction, is now available for direct use.

ECONOMIC CONSIDERATIONS

The economic merits of any new chemical process can only be judged by comparing its manufacturing cost, including a realistic amortization rate, with the equivalent figure for competitive processes. This is of course only true if it is assumed that all other factors such as, for instance, feedstock availability, ease of operation, attainable product purities, etc., do not add other arguments to the comparison. In the present case, these considerations amount to the following:

1. **Feedstock availability and price.** Unlike most of the other processes the Shell route for TPA/IPhA manufacture uses cheap and readily obtainable raw materials which are not subject to sudden changes in availability and price.
2. **Product purity.** Products of excellent purity are obtained by the Shell process, so that it is quite conceivable that the TPA produced might be used for fibre manufacture without the esterification step, which normally must be introduced for purification. Still, when further purification is necessary, the manufacture of a fibre-grade dimethyl ester is considerably easier and cheaper than it is with products of other processes.

In the course of the development of the Shell process for the manufacture of TPA and/or IPhA, the above-mentioned comparison has been improved and revised several times and it was consistently found that for European conditions, with a realistic price for *para*-xylene, the Shell process showed distinct advantages over all competitive routes.

("Production of Aromatic Diacarboxylic Acids," J. P. Fortuin, M. J. Waale and R. P. van Oosten, N. V. de Bataafsche Petroleum Maatschappij, The Netherlands. Originally presented at Fifth World Petroleum Congress, New York City, June, 1959.)

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5th WORLD PETROLEUM CONGRESS

More Data on Manganese Antiknock

Here is a new additive which can be used economically to improve the octane ratings of some gasoline blends. This report tells how it supplements TEL

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ANTIKNOCK COMPOUNDS will assume greater economic importance to the refining industry as octane levels of motor fuels continue to rise. Here is a report on a new antiknock compound. It is the methyl derivative of cyclopentadienyl manganese tricarbonyl and will be referred to as MD-CMT.

The new additive is a light amber, mobile liquid with a density of 1.39 and a manganese content of 24.7 percent. It has a freezing point of 34.6 F, a boiling point of 451 F, is essentially insoluble in water, and is miscible with organic solvents at room temperatures.

Another Report on MD-CMT
PETROLEUM REFINER,
Vol. 37, No. 7, p. 131
(July, 1958)

The ability of MD-CMT to increase the octane number of a commercial fuel can be correlated roughly with the TEL susceptibilty of the fuel.[1] However, the following discussion will cover some of the many attributes of the new additive to help in a closer evaluation of its usefulness to the refining industry.

MD-CMT Ups Octane. Favorable economics have led to the widespread use of TEL to achieve antiknock value. Since MD-CMT would be considerably more expensive than

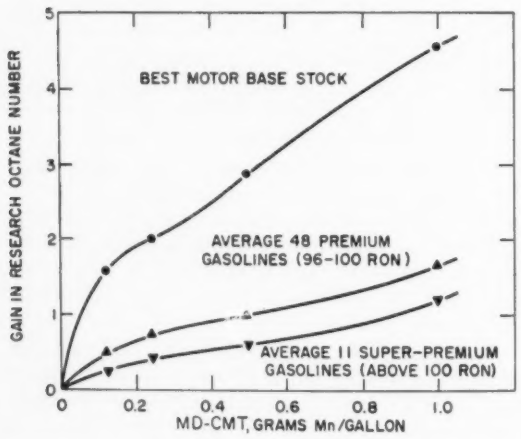

FIGURE 1—(above) The octanes of commercial fuels containing 3 ml TEL per gallon can be improved by the addition of the new additive.

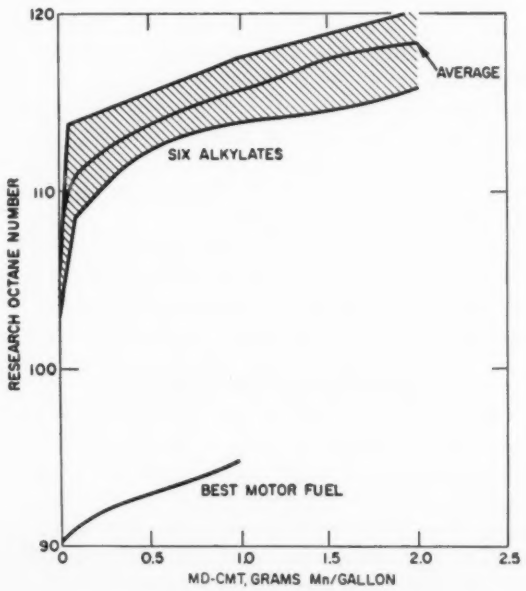

FIGURE 2—(right) Leaded alkylates show a remarkable response to the antiknock.

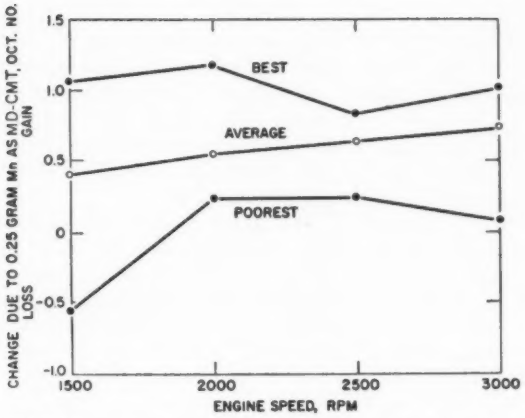

FIGURE 3—Here are the variations shown by three 11.1 compression ratio cars when burning nine leaded fuels.

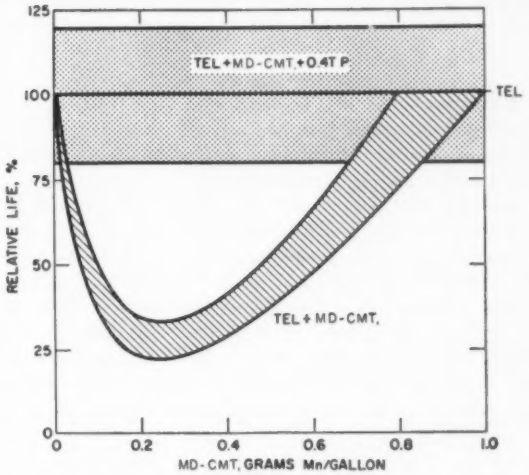

FIGURE 4—Certain phosphorus compounds will correct the harmfulness of MD-CMT on exhaust valve life.

TEL, major emphasis has been placed on evaluating it as a supplement to TEL. More than 100 different fuels of premium or super-premium quality have been rated with varying concentrations of manganese added as a supplement to TEL. The effectiveness of MD-CMT varied even more widely in these fuels than in the clear fuels.

The average gains in Research octane number from adding MD-CMT to various types of leaded fuels are shown in Figure 1. Of interest and importance here is evidence that the first small increment of MD-CMT added to the fuel is extremely effective. This is called the "promoter" effect, since it exceeds what would be expected from this concentration when added to a clear fuel. About 80 percent of the commercial fuels tested show this effect. As a matter of interest, a number of cyclopentadienyl manganese compounds exhibit equal ability to promote the action of TEL.

MD-CMT has been studied in a number of leaded pure hydrocarbons. The data do not help much in explaining the range of responses in leaded commercial fuels. The fact that high aromatic content and high octane number frequency occur together in modern refining practice explains fairly well the relatively low average effectiveness of MD-CMT in super-premium fuels. However, for a given aromatic concentration or base-fuel octane number, the effectiveness may vary widely. Concentration of olefins, saturates, or sulfur compounds cannot be correlated directly with MD-CMT response.

The average Motor-method response of commercial leaded fuels is about one-third the Research-method response. Super-premium gasolines show little or no Motor-method gain from small concentrations of MD-CMT. As will be made clear later, vehicle antiknock performance is better than would be indicated by the relatively poor Motor-method response.

Leaded alkylates show remarkable response to MD-CMT. None of the pure hydrocarbons which have been tested show a better response. These fuels exhibit the most dramatic evidence of the "promotor" action which small concentrations of MD-CMT exert in fuels containing TEL.

The Research octane numbers resulting from addition of MD-CMT to six leaded alkylates are shown in Figure 2. These six refinery streams were relatively similar both in base octane number and in response to TEL. Each showed a remarkable response to MD-CMT when it was used as a supplement to 3 ml of TEL; the gains in Research octane number averaged 6.4 for 0.1 gram of manganese in the form of MD-CMT. In the same fuels without TEL, an average of 0.4 gram would be required for an equal increase in RON. Unfortunately, this remarkable response decreases more or less linearly as other stocks are blended with alkylates.

The effects of base stock observed in laboratory engine tests can be exaggerated in vehicles, since volatility and the distribution of antiknock quality through the boiling range of the gasoline are important factors in the performance of an antiknock compound. This is emphasized in Figure 3 which shows the vehicle antiknock performance of MD-CMT when used as a supplement to tetraethyllead in fuels having 98-100 octane rating. The wide variations in effectiveness of the MD-CMT is immediately apparent. In this case, the variation can be explained by the difference in hydrocarbon composition of the fuels chosen for illustrative purposes.

The effect of engine speed of the antiknock effectiveness of the supplementary MD-CMT should also be observed. As will be noted, the effectiveness of the antiknock holds up much better over the range of engine speeds than would be predicted from conventional correlation equations relating ASTM Research and Motor method ratings to vehicle performance. This is mentioned here to emphasize that the vehicle performance of a fuel containing both tetraethyllead and MD-CMT cannot be predicted with existing equations. In general, the vehicle antiknock effectiveness of supplementary MD-CMT is much better than the Motor-method data would indicate.

Engine Durability. The principal factors which can affect the service life of an engine are exhaust-valve life, spark-plug life, engine wear,

and corrosion. At the Third World Petroleum Congress, J. B. Macauley[2] discussed engine durability when tetraethyllead is the antiknock compound in gasoline. Therefore, the following discussion will be confined to the solution of the problems introduced by MD-CMT.

The exhaust valve life is changed by adding MD-CMT to gasoline which already contains 3.0 ml of TEL per gallon as shown by the bottom portion of Figure 4. Valve life is drastically reduced as the first small increments of MD-CMT are added to the gasoline. But as the concentration is further increased, exhaust-valve life is restored to normal. This effect has been demonstrated on a variety of engines in many types of service. The MD-CMT concentration at which life becomes normal will vary, depending on the service. These results indicated that a corrective agent was very important to the commercialization of MD-CMT.

As the result of long search, certain phosphorus compounds have been found to be completely satisfactory corrective agents for the exhaust-valve problem. Enough phosphorus to provide 0.4T for the TEL present restores exhaust-valve life to normal, as also is indicated in Figure 4. Probably 0.3T phosphorus would be sufficient. The foregoing is a simple summary of the results of many millions of miles and thousands of hours of testing.

Sparkplug life in light-duty service is affected by MD-CMT when it is used as a supplement to 3.0 ml TEL, as shown in Figure 5. Failure occurs when the vehicle is brought to high speed. This failure is the result of low resistance of the deposits on the insulator. In this type of service, phosphorus reduces spark-plug failure, as does MD-CMT. Both phosphorus and MD-CMT produce deposits having improved electrical resistance at high temperatures. If the sulfur content of the fuel is quite low, MD-CMT may not increase spark-plug life and may even shorten it. In such cases, the phosphorus used to correct exhaust-valve life will provide spark-plug protection.

Figure 6 shows that MD-CMT can drastically reduce spark-plug life in severe-duty service. Under these conditions, spark-plug failure with supplementary MD-CMT can occur as a result of electrode or core bridging. This may hamper the use of supplemental MD-CMT at higher concentrations. Failure is usually evidenced as rough idle and misfire at low road speeds. Phosphorus does not reduce this type of failure. Thus, MD-CMT and phosphorus dramatically improve spark-plug life under one condition of engine operation and reduce it under another. Obviously, the concentrations of MD-CMT which will best reconcile these two effects must be determined by extensive testing.

When MD-CMT is used as the sole antiknock, no corrective agent is needed to insure excellent valve life. Spark plugs still may fail through electrode bridging, but much higher MD-CMT concentrations can be used than when tetraethyllead is present.

These are the principal durability effects of MD-CMT in gasoline. It is evident that over-all compromises are necessary as far as concentration is concerned. This is not unusual, since most engineering decisions involve compromise.

Wear and corrosion at both high and low operating temperatures are other engine durability factors which have been thoroughly investigated. When MD-CMT is used as a supplement to tetraethyllead, the effect on engine wear is practically negligible. When it is used as a primary antiknock, engine wear may be considerably reduced, particularly under conditions conducive to cold corrosion.

Generally speaking, contamination of lubricating oil with metallic com-

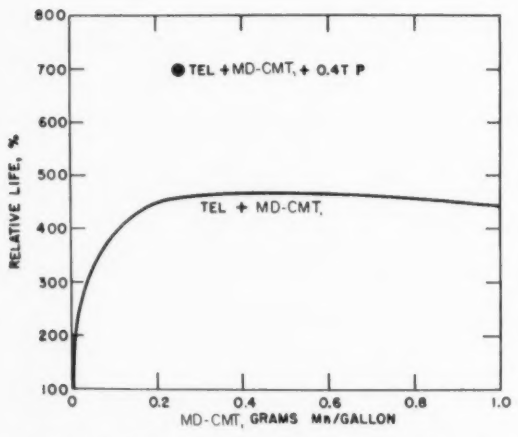

FIGURE 5—(above) Spark plug life during light-duty service is improved.

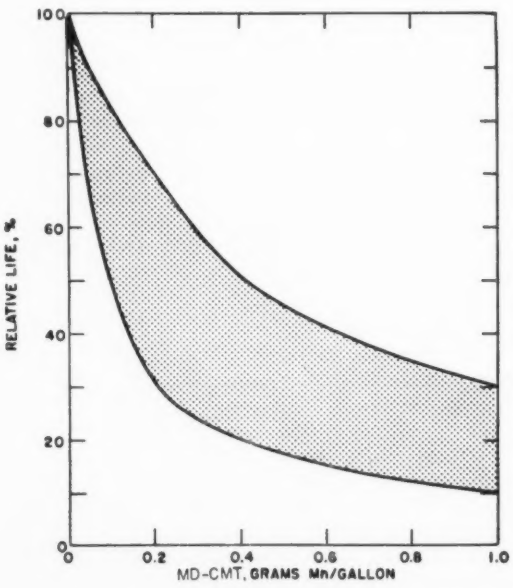

FIGURE 6—(right) During heavy-duty service, however, spark plug life is decreased by the addition of the new antiknock.

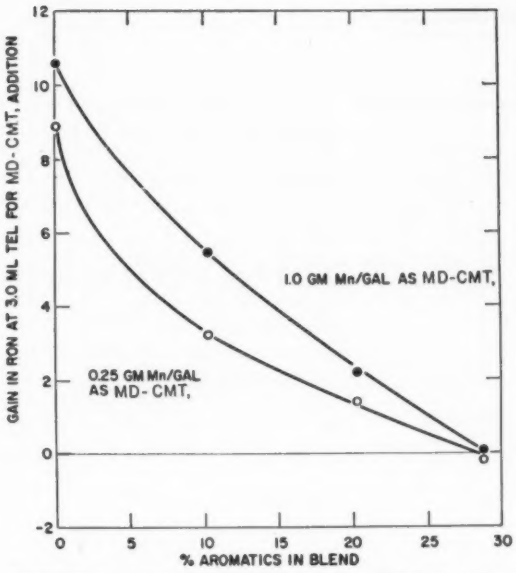

FIGURE 7—Aromatics lower the response of leaded gasolines to MD-CMT.

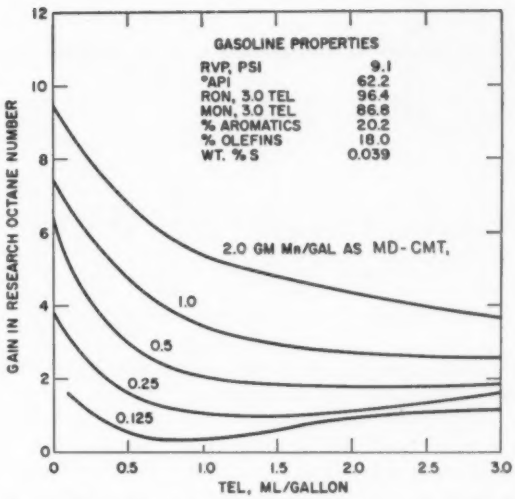

FIGURE 8—The joint behavior of TEL and MD-CMT is needed to make an economic balance between the two. Here is their response in one gasoline.

pounds tends to reduce oxidation resistance and increase bearing corrosion. However, when properly compounded oils are used, bearing corrosion and oil oxidation are not problems with MD-CMT.

Engine-deposit effects are becoming increasingly important. Much has been said and written about increase in octane-number requirement (ORI), surface ignition, and rumble which is simply another manifestation of surface ignition caused by combustion-chamber deposits. Here again, the presence in gasoline of any organometallic different than tetraethyllead results in different deposit effects. To evaluate the effects of antiknocks and other gasoline additives, the Ethyl Laboratories use a fleet of passenger cars operating under carefully-controlled conditions on a simulated city-country schedule. This schedule is statistically designed to provide results which have the greatest possible significance at minimum expense.

Over a million miles of testing have been conducted to study the effect of MD-CMT on deposit problems. Inclusion of MD-CMT with tetraethyllead in gasoline has no significant effect on octane-requirement increase. However, it does have some tendency to increase rumble and surface ignition. The phosphorus used to provide exhaust-valve durability adequately controls these problems at present compression ratios.

When MD-CMT is used as a primary antiknock compound, without tetraethyllead, it tends to reduce ORI, and many fuels containing it are substantially free of surface ignition and rumble. This may become an increasingly important factor as compression ratios and octane numbers are increased.

What MD-CMT Will Cost

As a Primary Antiknock. MD-CMT would compete with TEL; so its ultimate commercial price would define the extent of its use. A price of 9.85 cents per gram of manganese content, exclusive of any corrective agent, can be assumed for discussion, based on process development to date. This is about four times the price of TEL, based on content of metallic lead. When used alone, manganese rarely is four times as effective as lead.

As with TEL, we can plot octane number against manganese concentration, using TEL susceptibility charts, and obtain fair correlations above 0.25 gm of Mn per gallon. The response of the 24-premium average is given in Table 1, after having been smoothed by plotting as described. Incremental octane costs are also shown. The costs favor TEL by some margin. Use of MD-CMT as a primary antiknock will require much lower costs than now indicated by process work.

As a Supplement to TEL. On top of TEL, very low concentrations of MD-CMT give unusually good octane response, depending on gasoline composition. This was illustrated earlier in Figure 1. Typical data on refinery streams and average gasolines are given in Table 2. Certain components, particularly alkylates and paraffinic naphthas, have remarkable responses. As average gasoline composition is approached, however, the octane gains diminish.

TABLE 1—Average Response of 24 Premium Gasolines to Antiknocks

MD-CMT			TETRAETHYL LEAD		
gms. Mn./gal.	RON	¢/RONB[1]	ml TEL/gal	RON	¢/RONB[1]
0.	92.0	....	0.	92.0	....
0.25	95.1	6.7	0.25	93.6	2.0
0.5	96.3	9.3	0.5	94.7	2.7
1.0	97.8	14.7	1.0	96.1	4.2
2.0	99.6	26.0	2.0	97.7	7.4
			3.0	98.7	10.7

[1] Costs are incremental, indicative of rate of cost at specified concentration. Price of TEL used—0.22¢/ml; Price of MD-CMT used—0.85¢/gm Mn.

Although we have not isolated the variables that contribute to behavior, it is known that aromatics lower the response of leaded gasolines to MD-CMT. Figure 7 shows the effect of aromatics in a case where alkylate, isomer, and reformate were varied in concentration to make gasolines of about 103 RON. Effects of the specific aromatics have not been defined. Although many exceptions have been found, most responsive fuels have aromatic contents below 30%.

Balancing TEL and MD-CMT. Until the joint behavior of TEL and

TABLE 2—MD-CMT As a Supplement to TEL in Gasolines and Components Containing 3.0 ML TEL

	Research ON @ TEL		Gain in RON @ 3.0 TEL gms/gallon—Mn as MD-CMT			
Component	0.0	3.0	0.125	0.25	0.5	1.0
Alkylate (Avg. of 6)	93.8	104.7	6.6	7.5	9.2	11.3
Natural Gasoline	71.0	88.0	2.9	4.2	5.0	5.8
Isomer of C_5-C_6	85.0	97.0	4.6	5.0	5.8	7.4
Catalytic Cracked Naphtha	93.4	98.6	0.3	0.5	0.8	1.1
Catalytic Reformates						
35.0% Aromatics	88.1	98.9	1.1	1.2	1.3	1.8
62.5% Aromatics	97.8	102.1	—0.1	—0.1	—0.1	—0.1
Average Regular Gasoline	83.7	93.6	1.6	2.0	2.2	2.9
Average Premium Gasoline	91.6	98.5	0.5	0.7	1.1	1.8

MD-CMT can be predicted, few conclusions can be drawn regarding the economic balance of the two in a given gasoline. Figure 8 gives data that are typical of many of the fuels that respond favorably to a mixture of TEL and MD-CMT. The higher concentrations of MD-CMT (0.5 grams metal per gallon and above) give curves that would be expected: high response at low TEL levels and less response as TEL is increased. The lower manganese concentrations, however, exhibit a minimum response in the TEL range of 0.5 to 2.0 ml per gallon. Thus, the "promoter" effect of MD-CMT occurs at high TEL levels where economic balance between TEL and MD-CMT will normally occur. Note too, at the 3.0 TEL level, how unit effectiveness of MD-CMT drops off with concentration. The most attractive refining use of MD-CMT will be at concentrations of 0.5 grams metal per gallon and below, in highly leaded fuels.

Balancing TEL, MD-CMT, and Reforming. The octane level of premium gasoline often sets the level of catalytic reforming in a refinery. In such cases, maximum TEL in the premium grade is generally economic. Table 3 gives a sample cost study for a 50,000-bpd refining operation in which supplemental MD-CMT would be found economic at the assumed price. The refinery produces 54 percent gasoline, based on crude-oil charged, and 40 percent of the gasoline is premium grade of 100 RON (Case 1); the regular grade is 93 RON. Reforming severity (expressed as debutanized reformate RON at 3.0 ml TEL) is adjusted to the level required to compensate for low-quality stocks in the premium. The reformate component constitutes 40 percent of the premium blends, the remainder being alkylate, catalytically cracked naphtha, and light virgin naphthas. The TEL content of the regular gasoline is 2.0 ml per gallon, not allowing for blocked-out operation of the reformer.

TABLE 3—MD-CMT and Reformer Severity —50,000-BPD Refinery

Case	1	2	3	4
Premium Gasoline				
RON Spec	100	101	101	101
TEL, ml/gallon	3.0	3.0	3.0	3.0
MD-CMT, gm./gallon	0	0	0.125	0.25
RON, ex MD-CMT	100	101	100.5	100.2
RON, Reformate Component	95.2	98.0	96.6	95.8
Production, B/D	11,200	11,020	11,100	11,150
Regular Gasoline				
RON Spec	93	94	94	94
TEL, ml/gallon	2.0	2.3	2.5	2.8
Production, B/D	16,800	16,530	16,660	16,730
Economics Additional Process Costs, $/D incl. Yield effects)	0	1,950	950	560
Additional TEL Costs, $/D	0	360	720	1,210
MD/CMT Cost, $/D	0	0	495	995
Total Additional Costs	0	2,310	2,165	2,765
Savings vs Case 2	....	....	+145	—455

Three cases (2, 3, 4) are shown in Table 3 for increasing gasoline octane number. Case 2 uses no MD-CMT, increases reformate quality to 98.0 RON at 3.0 ml TEL, and increases TEL in regular to 2.3 ml per gallon. Cases 3 and 4 assume the use in premium of 0.125 and 0.25 gm manganese per gallon, respectively. The gasoline is average with respect to hydrocarbon type. Therefore, only average MD-CMT response is assumed: 0.5 RON for 0.125 grams MD-CMT and 0.8 RON for 0.25 grams MD-CMT, as metal, on top of 3.0 ml TEL per gallon. With MD-CMT supplementing TEL, lower reformate qualities and lower-octane base blends are permitted. The lower reformate qualities also occasion higher TEL in regular.

Costs are shown to favor MD-CMT at the 0.125-gram level, but the higher level is not economic. This example assumes no selective blending to capitalize on MD-CMT response. Thus, it is felt that many refinery situations will find MD-CMT more attractive than severe reforming.

Impact of MD-CMT on Refining. Processes that produce components having good MD-CMT response will bear review. Alkylation and isomerization, for example, may be more attractive with MD-CMT available than they would be otherwise. A limited quantity of alkylate will go farther in blending when MD-CMT is used.

Natural gasolines have excellent response to MD-CMT.[3] Laboratory work has demonstrated that premium gasoline blends can tolerate significantly larger additions of natural gasoline for volatility purposes when octane number is maintained by supplementary MD-CMT. Light virgin naphthas also benefit from MD-CMT. These naphthas are needed in most gasolines for volatility control, and MD-CMT will permit their greater use in a given blend.

Catalytic-reforming severities will be modestly lower for a given refinery octane level. This will mean slightly less aromatics in a gasoline than otherwise, along with more paraffins. Directionally this will help road octane performance.

Blending of gasolines will be more flexible in a two-antiknock system. Closer controls can be applied to costly processing, in order to avoid high-cost octane numbers. The octane-number potential represented by a supplementary antiknock could well permit a closer timing of capital investments for octane-improvement processes, and perhaps, in cases, obviate the investments altogether.

Excerpts from a presentation before the Fifth World Petroleum Congress, New York, May 30-June 5, 1959.

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Get More Isomers at Low Temperature

Esso's new isomerization process operates at low temperatures to take advantage of better equilibrium conditions. Here are projected octane and cost data

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THE LARGE AMOUNT of low octane light virgin naphtha presently going into motor gasoline pools makes incremental improvement of pool octane increasingly difficult. As octane levels continue to rise, refiners will have need for an economical process to upgrade this fraction of crude oil. Figure 1 shows approximate octane levels of major components in a projected 1960 gasoline pool for a typical United States (Gulf Coast location) refinery.[1] It is seen that the C_5/C_6 virgin naphtha, which comprises 15 to 20 volume percent of the pool, is by far the lowest octane component. This tends to place a ceiling on pool octane. Furthermore, with low octane in a major low-boiling gasoline component, it is becoming increasingly difficult to produce premium grade gasolines of required volatility and road octane performance. This is especially true in refineries maximizing middle distillate

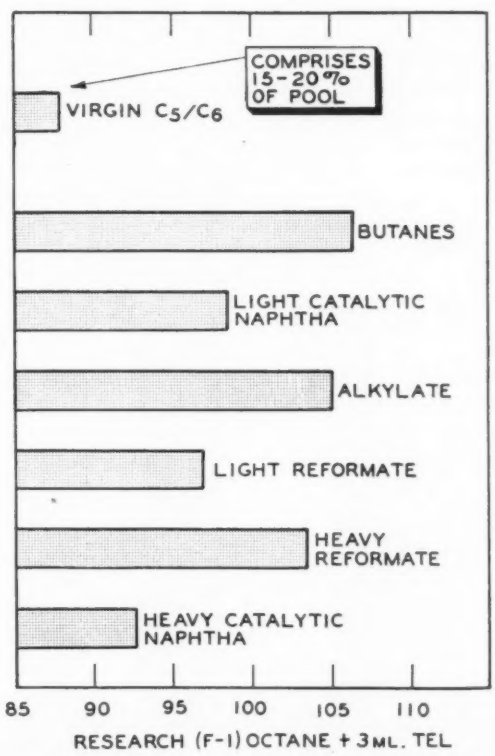

FIGURE 1—These will probably be the major components in a 1960 motor gasoline pool.

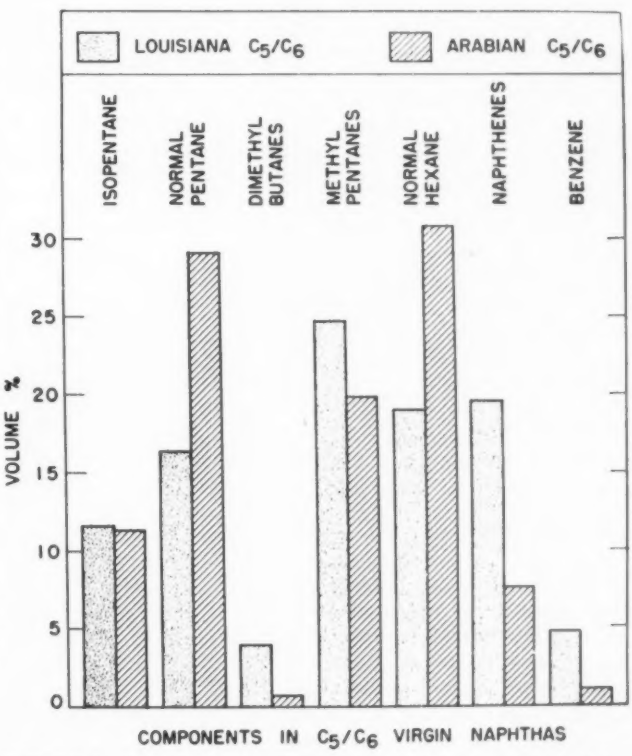

FIGURE 2—There is a predominance of low octane paraffins in light virgin naphthas.

and fuel oil yields, where catalytic cracking is not employed.

The major components in light virgin naphthas are shown in Figure 2. There is a predominance of low octane paraffins — *n*-pentane, *n*-hexane, and methyl pentanes. The Louisiana C_5/C_6 is a relatively good light virgin naphtha, while the Arabian is a typical low octane C_5/C_6 virgin naptha. These stocks are discussed in detail later.

Esso Research and Engineering Company is developing an isomerization process for upgrading such light virgin naphthas. This article discusses that process.

Importance of Reaction Temperature. The attractiveness of a C_5/C_6 isomerization process is critically dependent upon obtaining high conversion to the most branched isomers. High conversion means high octane improvement per pass and the reduction or elimination of costly product recycle. Conversion in isomerization is limited by the thermodynamic equilibrium, which is much more favorable for branched paraffins at lower temperatures. This is particularly true with respect to the concentration of 2,2-dimethyl butane in the C_6 paraffins. Table 1 shows experimentally observed equilibrium concentrations for C_5 and C_6 paraffins and C_6 naphthenes at three temperature levels. Figure 3 shows the important effect of reaction temperature on maximum product octane attainable in isomerization of C_5 and C_6 paraffins without recycle. The estimated octane levels in Figure 3 are based on the equilibrium distributions (Table 1) of the C_5 and C_6 paraffins. Unless otherwise indicated all octane numbers reported in this paper are ASTM values. Octane numbers above 100 are expressed on the CRC (Coordinating Research Council) scale.

The high temperature level for C_5/C_6 isomerization, 700-900 F., is the approximate range of several recently developed "Hydroisomerization" vapor phase process[3,4,5] which use supported precious metal catalysts. The 200-250 F. temperature range is typical of the so-called "$AlCl_3$-Sludge" process,[2] in which a C_5/C_6 feed is isomerized in the liquid phase in the presence of an $AlCl_3$-hydrocarbon complex as the catalyst. The 80-120 F. temperature range for isomerization is representative of the new Esso low temperature process described in this paper.

TABLE 1—Effect of Temperature on Isomerization Equilibria

Temperature Level—F.	Equilibrium Composition,* Volume %		
	New Esso Process 80-120	$AlCl_3$ Sludge Processes 200-250	Hydroisomerization Processes 700-900
C_5 Paraffins			
Isopentane	90	85	62
n-Pentane	10	15	38
C_6 Paraffins			
2, 2-Dimethyl Butane	52	39	10
2, 3-Dimethyl Butane	10	10	8
2-Methyl Penthane	23	28	37
3 Methyl Penthane	9	13	20
n-Hexane	6	10	25
C_6 Naphthenes			
Methylcyclopentane	15	35	87
Cyclohexane	85	65	13

* Approximate values, based on selected experimental data rather than thermodynamic calculations. References: 4, 6, 7, 8, 9, 10.

Figure 3 shows that the Esso Low Temperature Process has a potential advantage in once-through product octane, over the hydroisomerization type processes, of more than 5 octanes in the C_5 paraffins and 9 octanes in the C_6 paraffins. On the other hand, equilibrium C_6 naphthenes have higher octane at the higher temperature. However, since typical refinery C_6 fractions contain no more than 10-20 volume percent naphthenes, the effect of paraffins predominates. In pentane isomerization, recycle of unconverted *n*-pentane is feasible by fractionation of the product. Higher conversion per pass through the reaction zone does, however, reduce the cost of octane improvement of the pentane fraction.[4]

In the case of C_6 fractions the boiling points of some of the paraffin isomers are very close to each other. The attendant high cost of superfractionation required to separate the low octane isomers militates against product recycle in hexane isomerization. The increasing need for an economical process to upgrade the C_5 and C_6 fractions of light virgin naphtha indicates the desirability of a truly high conversion isomerization process. The new process discussed in this paper gives high conversions to isoparaffins and makes it possible to upgrade C_5/C_6 feeds to attractive octane levels without product separation and recycle.

Pilot Plant Results. Extensive pilot plant studies have been conducted during development of the process. In typical operations a combined C_5/C_6 naphtha feed is first pretreated to remove impurities which might result in poor operability or excessive catalyst consumption. The feed is then isomerized in the liquid phase at the very low temperature of 80-120 F, made possible by the

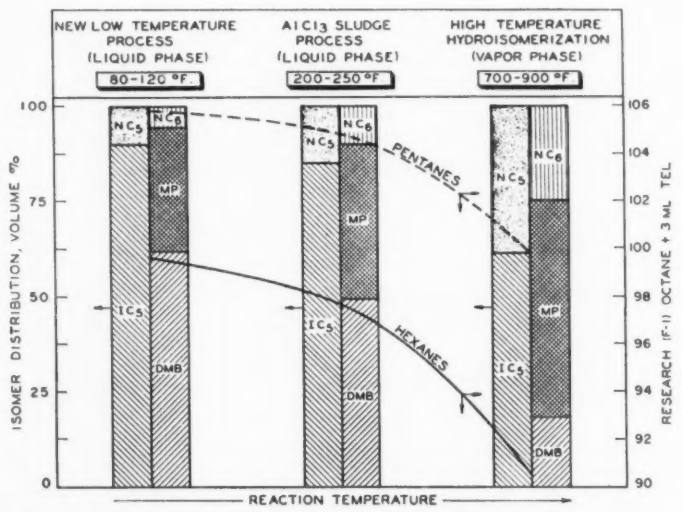

FIGURE 3—Higher isomerization temperatures give less desirable equilibrium compositions of C_5 and C_6 paraffins.

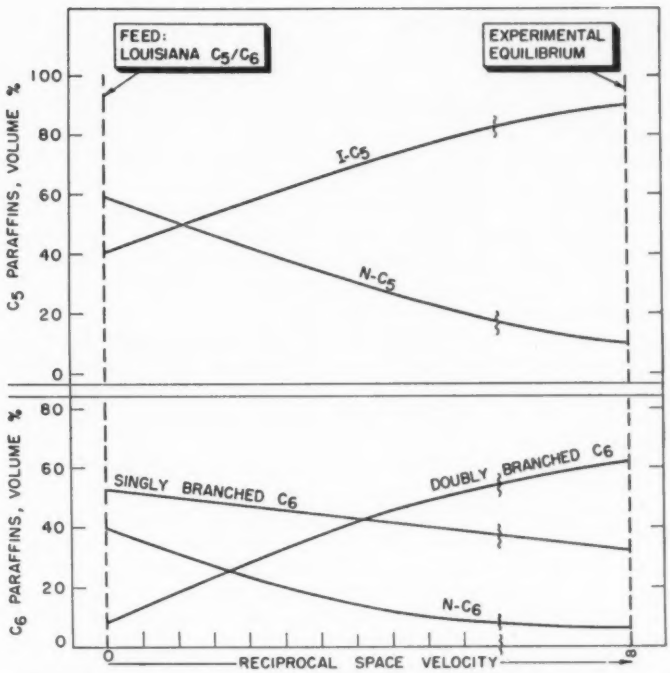

FIGURE 4—Isomerization severity influences the isomer distribution of C_5/C_6 paraffins (Reaction temperature is 80-120 F).

use of an extremely active catalyst.

As discussed above the favorable thermodynamic equilibrium existing at the low reaction temperature permits high once-through conversion. A general picture of the kinetics of the process is shown in Figure 4. The curves showing paraffin isomer distribution as a function of reciprocal space velocity (reactor holding time) are based on pilot plant data obtained on the Louisiana combined C_5/C_6 naphtha feed. For both the C_5 and C_6 paraffins the isomerization is a first order reversible reaction with respect to disappearance of the normal isomer. As equilibrium is approached it is seen that the effect of the reverse isomerization reactions becomes appreciable. This is indicated in Figure 4 by the break in the scale of the abscissa (reciprocal pace velocity) at a point where about 92 percent of the hexane exists as branched isomers.

At this hexane conversion level, for the Louisiana combined C_5/C_6 feed, 80-85 percent of the C_5 fraction exists as isopentane. Although the reaction rate for n-hexane is considerably higher than that for n-pentane, it is possible to isomerize the C_5 and C_6 fractions as a combined feed to high conversion levels on both fractions. The catalyst of the Esso process is both active and selective at the low temperature employed. Cracking and disproportionation, which tend to occur at high conversion levels in hexane isomerization, are minimized.

Figure 4 also shows the high concentration of doubly branched C_6 isomers (2,2- and 2,3-dimethyl butane) produced at high n-hexane conversion levels. This contributes substantially to the octane rating of the C_5/C_6 isomerizate. The effect of isomerization severity, again expressed as reciprocal space velocity, on octane of the isomerization from Louisiana C_5/C_6 is seen in Figure 5, which complements Figure 4. Above 98 octane (Research + 3 ml. TEL per U.S. gallon) which corresponds to 92 percent C_6 branched isomers in Figure 4, it is increasingly difficult to upgrade the naphtha further as equilibrium is approached. Of course, higher conversions and thus higher octane levels are possible, but much longer reactor holding time is required for incremental product improvement above this level.

Typical feed and product data from pilot plant operations are shown in Table 2. The virgin Louisiana C_5/C_6 feed is a good quality light virgin naphtha, having a relatively high Research (+ 3 ml. TEL) octane rating of 89.5. Even so, isomerization of this feed upgraded it approximately 8.5 octane numbers to a 98.0 level. The C_5/C_6 fraction from an Arabian crude. This feed contains less benzene and naphthenes and substantially more n-pentane and n-hexane than the Louisiana C_5/C_6. Thus, it is a lower octane feed. Since isomerizate octane number is limited by equilibrium considerations, the product from the Arabian feed has an octane number about equivalent to the product from the higher quality Louisiana feed. Therefore, the low temperature once-through isomerization process upgrades the Arabian feed by a very substantial 14.5 Research octane numbers.

TABLE 2—Isomerization Data

	VOLUME PERCENT			
	Louisiana C_5/C_6		Arabian C_5/C_6	
Component	Feed	Product*	Feed	Product*
Normal Pentane	16.3	4.8	29.1	7.1
Isopentane	11.6	23.1	11.3	33.3
Normal Hexane	19.0	4.4	30.4	4.1
2, 2-Dimethyl Butane	1.9	20.7	0.0	25.2
2, 3-Dimethyl Butane	2.1	5.0	0.7	4.6
2-Methyl Pentane	15.3	11.4	11.3	12.0
3-Methyl Pentane	9.4	6.2	8.6	5.1
Cyclopentane	2.3	1.8	0.7	0.1
Methylcyclopentane	10.9	2.2	5.4	0.9
Cyclohexane	6.4	15.6	1.5	6.6
Benzene	4.8	4.8	1.0	1.0
Normalized Total	100.0	100.0	100.0	100.0
Reid Vapor Pressure, Psig	9.2	11.1	10.0	12.6
ASTM Octane Ratings				
Research (F-1) + 3 ml. TEL	89.5	98.0	84.0	98.5
Motor (F-2) + 3 ml. TEL	86.6	101.0	83.9	101.5

* Converted once-through at 80-120F. C_5/C_6 yield is greater than 99 vol. %.

C_5/C_6 Isomerizate as a Motor Gasoline Component. The data in Table 2 show that high conversion isomerization by the Esso low temperature process can upgrade C_5/C_6 virgin naphthas to a Research octane level approximately equivalent to that of other major components in motor gasoline pools. Figure 6 points up further the excellent quality of the C_5/C_6 isomerizate. The isomerizate has a very high Motor octane rating. For instance, at a level of 98 Research + 3 ml. TEL, the rating by the Motor method is 100 octane with 3 ml. TEL/gallon. The high concentration of branched paraffins in the isomerizate gives this material a decided advantage in lead susceptibility and Motor octane rating over typical catalytic reformates,

which are rich in aromatic hydrocarbons. The increasing importance of Motor octane in producing gasolines of high road performance for modern automobiles should make the low temperature isomerization process especially attractive for improving motor gasoline pools.

While C_5/C_6 isomerization may soon be needed in many refineries as a pool octane improvement step, use of the process to produce a high octane blending component is especially interesting. Even in cases where a refiner can manufacture enough octanes to meet pool requirements, it may be very difficult to separate the high octane streams required to produce a premium grade gasoline some 7 to 9 octane numbers higher than the regular grade. Volatility specifications may also pose a problem in high octane gasoline blending. Thus, high octane ratings and inherent volatility of C_5/C_6 isomerizate make it an excellent blending component for premium gasoline production.

Figure 7 shows the Research octane blending characteristics of low temperature C_5/C_6 isomerizate when it is blended into a very high octane pool rich in aromatics. This is a typical future pool for premium gasoline. While the straight rating on the isomerizate is 98 octane on a Research basis, it blends into the pool as if it had a 103-104 Research rating. This is referred to as the blending octane value. (Octane blending values in Figures 7 and 8 were determined on blends containing 25 volume percent of the component and 75 percent of the pool indicated.) The isomerizate blends at a value near the level of the high octane pool. It is only slightly inferior to a butylene alkylate in this respect.

The C_5/C_6 virgin naphtha, from which the isomerizate was produced, is too low in octane to be considered for blending into future premium gasolines. Therefore, its blending value in a lower octane pool for future regular grade gasoline is given in Figure 7. The difference between the blending octane values shown for the virgin naphtha and the isomerizate is 11-12 numbers, and this represents the amount by which the isomerization process upgrades the Louisiana C_5/C_6 fraction as a gasoline blending component.

Figure 8 shows the important Motor octane blending characteristics of the same isomerized C_5/C_6 naphtha. Although the isomerizate has a Motor octane blending value lower than its straight rating, it blends at a level well above that of the high octane pool. In other words, the isomerizate would improve the Motor octane rating of the future premium grade gasoline pool. In this respect it is approximately equivalent to the butylene alkylate. Figure 8 also shows that low temperature isomerization would appreciate the blending value of the Louisiana C_5/C_6 naphtha by 11 octane numbers on a Motor method basis.

C_5/C_6 Isomerizate for Aviation Gasoline. While the major need for isomerization is to upgrade light virgin naphtha in motor gasoline pools, C_5/C_6 isomerizate is a potential aviation gasoline blending component. Table 3 shows the aviation anti-knock ratings of a low temperature isomerizate compared to ratings of a high grade alkylate and a light virgin naphtha, which are typically the best and poorest components, respectively, in aviation pools. The relatively high lean and rich ratings of the C_5/C_6 isomerizate would make it possible to back out some of the light virgin naphtha base and to blend some of this better component into aviation gasoline, thus reducing the requirement for high octane alkylate. This would have the effect of extending the supply of aviation gasoline, or of making more high octane alkylate available for use in premium grade motor gasolines. Blending studies have shown that up to 20 volume percent of low temperature C_5/C_6 isomerizate can be

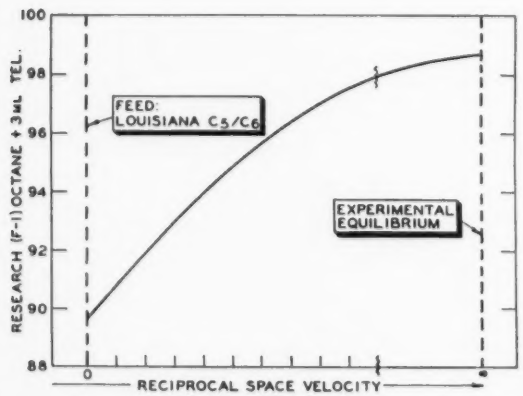

FIGURE 5—(above) Product octanes go up under more severe isomerization conditions.

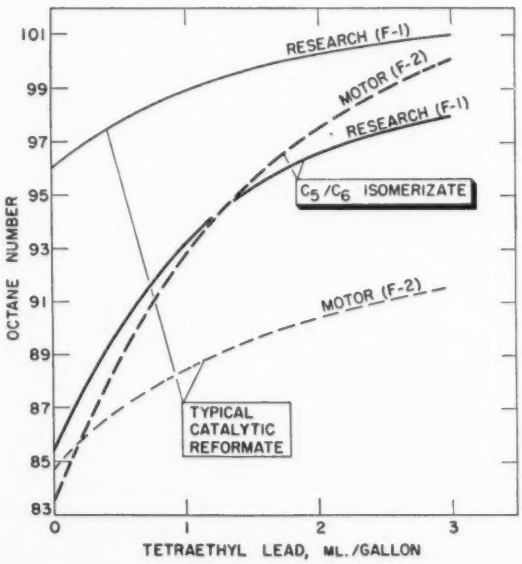

FIGURE 6 (right)—The C_5/C_6 isomerizate from a Louisiana virgin feed compares very well with a typical catalytic reformate.

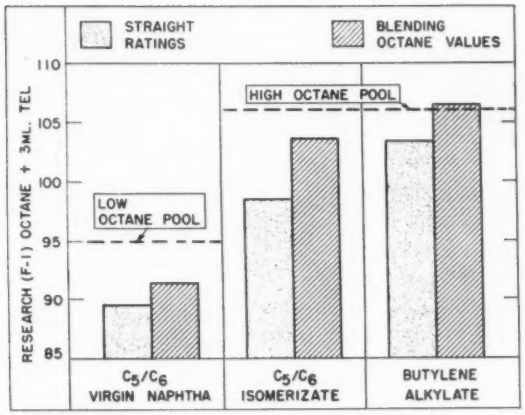

FIGURE 7—The C_5/C_6 virgin naphtha is too low in octane to be considered for a premium gasoline blend.

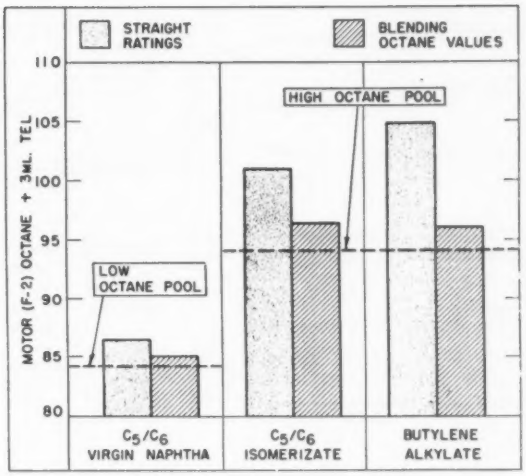

FIGURE 8—Isomerizate would improve the motor octane rating of most premium gasoline blends.

included in an aviation pool to produce a high grade 115/145 (lean/rich) aviation gasoline of required volatility and vapor pressure.

Process Economics. Estimates of the process investment and direct operating costs for low temperature C_5/C_6 isomerization plants of two sizes are given in Table 4. These costs include feed preparation to remove certain impurities, present in most feeds, which might result in poor operability or excessive catalyst consumption. It is assumed that a feed of suitable boiling range is available. Therefore, no feed fractionation costs are included. Direct operating costs include operating labor, catalyst and chemicals, utilities and maintenance.

The process investments shown in Table 4 are approximate values and would, of course, vary considerably with engineering standards and location. It should be noted again that the Esso Low Temperature Process makes a high octane product with once-through isomerization. This eliminates the high investment and operating costs of superfractionation for product recycle required in higher temperature processes to reach a comparable octane level.

Unit costs for octane improvement (¢/octane barrel) are affected by such factors as plant size and feed quality. Since product octane number is limited by equilibrium at the temperature employed, lower unit costs for a given processing cost can be obtained with low octane feed stocks, such as the Arabian C_5/C_6. It has been assumed that a total of C_5/C_6 virgin naphtha is fed to the isomerization process. The addition of a feed deisopentanizer would permit some further octane improvement and add flexibility for gasoline blending. This might or might not lower unit cost of octane improvement, depending upon isopentane content of the feed. In some refineries feed stocks of very high n-paraffin content are available as a result of superfractionation and/or extraction operations. This provides particularly favorable circumstances for economical octane improvement by isomerization.

It is estimated that total costs of octane improvement by the Esso Low Temperature Process are generally in the range of 5 to 10 ¢/octane barrel, depending upon plant size and feed quality. This includes direct costs, normal overhead charges for an average refinery, and three-year amortization of the plant. This low cost for motor gasoline octane improvement is very attractive to refiners at present and projected octane levels.

TABLE 3—C_5/C_6 Isomerizate Compared to Other Aviation Gasoline Blending Components

Component	AVIATION ANTI-KNOCK RATINGS*	
	Lean (ASTM-D614)	Supercharge Rich (ASTM-D909)
C_5/C_6 Isomerizate	109	129
Alkylate	130	163
Light Virgin Naphtha	90	97

* Ratings at 4.6 ml TEL/U.S. Gallon. Numbers above 100 are Performance Numbers, below 100 are Octane Numbers.

TABLE 4—Economics for Low Temperature Isomerization Process

Plant Size, B/CD	5000	17,000
Process Investment, $/BPCD	400	250
Direct Operating Costs, ¢/B	35	30

Original presentation was before the Fifth World Petroleum Congress, New York, May 30-June 5, 1959.

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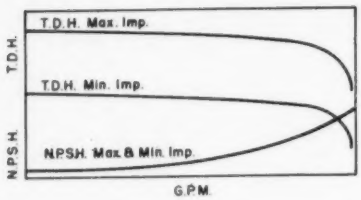

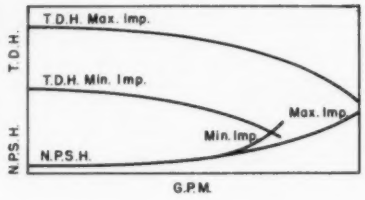

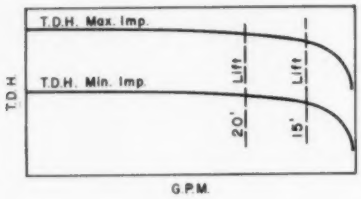

FIGURE 1—(upper left) Same NPSH curve applies.

FIGURE 2—(above) Different NPSH curves for these pumps.

FIGURE 3—(lower left) Lift curves are vertical lines.

Tests show relation between . . .

NPSH and Impeller Size

Lab tests show pump may have same NPSH for both maximum and minimum impeller diameter

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IS NPSH a function of the impeller diameter? This question can be answered with yes and no. The only sure way to determine the NPSH characteristics of a centrifugal pump is by making a series of lift tests from which the NPSH curves can then be calculated. From such tests, we find that some sizes and types of pumps have the same NPSH curve for maximum and minimum impeller diameters; other pumps show different NPSH curves for maximum and minimum impeller diameters. Based on our experience in testing a large number of pumps, it is fairly easy to predict the class of NPSH requirements in which a given pump falls.

If the head-capacity curves of a pump break at approximately the same GPM, regardless of impeller diameter, the same NPSH curve will apply to the maximum impeller as to the minimum impeller or any impeller diameter in between (Figure 1).

Other pump characteristics show a decrease in the maximum capacity with a reduction in impeller diameter. Pumps of this type have different NPSH curves for the maximum and minimum impeller diameter (Figure 2).

Theoretically, the NPSH of a pump is determined by the impeller inlet conditions. The physical dimensions of the impeller eye and vane entrance do not change when trimming an impeller from full diameter to a smaller diameter. Therefore, we could expect that the NPSH at a given capacity would remain the same regardless of the impeller diameter. This is correct within the capacity range from shutoff to about the maximum efficiency point at the minimum impeller diameter. At larger capacities, laboratory tests show that for the same capacity, i.e. for the same impeller eye and entrance velocities, a higher NPSH may be required by the minimum impeller diameter than by the full diameter impeller.

Example. The NPSH curves of a typical single stage pump, at 1,750 rpm with impeller at 11 inches maximum diameter and 7¾-inches minimum diameter will be analyzed.

The maximum efficiency at full diameter is at a capacity of 1,700 gpm and 102 feet T.D.H. At that point the curve shows 15½ feet NPSH required. At the same capacity, the minimum diameter shows a T.D.H. of 14 feet only and the NPSH required is 28 feet. This is at the break-off point of the 7¾-inch impeller diameter characteristic.

NPSH and suction lift are related by the following formula:

$$Hs = Hp - Hsv - Hvp$$

where

Hs = total suction lift in feet of fluid
= Hz + Hf (static lift + entrance and friction losses)
Hp = absolute pressure on suction level in feet of fluid
Hsv = NPSH in feet of fluid
Hvp = absolute vapor pressure of fluid at pumping temperature, expressed in feet.

Using the above NPSH values at 1,700 gpm, 11 inches and 7¾-inch diameter impellers and using Hp = 33 feet (29.1 inches Hg. atmospheric pressure) and Hvp = 1.0 feet (75° F. water temperature), we will have:

Hs (11-inches Imp. diameter) =
33 — 15½ — 1 = 16½ feet
Hs (7¾-inch Imp. diameter) =
33 — 28 — 1 = 4 feet

From the above Hs values it is reasonable that the pump will handle a 4-foot suction lift at the end of the 7¾-inch impeller diameter characteristic. But it is obvious that it could not handle 16½-foot suction lift with an impeller diameter producing only a total dynamic head of 14 feet.

NPSH curves may be different in a variable degree, depending on pump characteristics, for maximum diameter and minimum diameter impeller. Some curves for single stage-double suction pumps show suction lift lines for maximum capacity at various constant lifts.

For some pumps, these lift curves are straight vertical lines, indicating constant suction lift for a given capacity regardless of impeller diameter. This would mean that the same NPSH applies to any impeller diameter (Figure 3). Other curves show a vertical suction lift curve over part of the trim diameters, and at the smaller impeller diameter, the lift curve angles over to the left. That is, the same suction lift at the minimum impeller diameter will occur at a smaller capacity. ##

How to Design Multitube Condensers

Recommended design equations for vertical, horizontal and extended surface tube vapor condensers have been resolved into nomograms for rapid solution

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Davis Engineering
A Division of American Metal Products Co.
Elizabeth, N. J.

BASING THE derivation on the basic Nusselt equations and subsequent modifications by Kirkbride and Katz, a group of expressions has been developed for multitube vapor condensers. The concept of equivalent number of condensate streams (for horizontal units) has been developed in quantitative form for all the industrially important tube-field orientations.

The nomograms of the resulting equations have been drawn, employing recent data on thermal conductivity, and, in general, up-to-date physical property factors.

The turbulence correction factor of Katz and his co-workers has been nomographed. This can also serve for the purpose of correlating future data.

The two distinct modes of condensation are:

1. Dropwise condensation

2. Filmwise condensation

Simultaneous occurrence of both mechanisms is also possible. Because it is almost impossible to control, dropwise condensation is rarely encountered in practical design.

Baer and McKelvey[3] analyzed the mechanism of heat transfer in film condensation. They enumerate the various resistances to the heat flow as:

1. Convective transfer from the vapor to the condensate film-vapor interface.

2. Condensation at the interface.

3. Conduction and convection through the condensate film.

In the design of a vapor condenser with no noncondensable gas present, the conduction process, 3, is controlling.

REVIEW OF NUSSELT EQUATIONS

The basic equation of heat convection is due to Newton—

$$q = hA\Delta t \qquad (1)$$

Fourier's equation for heat conduction is

$$q = \frac{k}{Y}A\Delta t \qquad (2)$$

Jakob[14] pointed out that any problem in convective heat transfer should be regarded as a special case of heat conduction with super-imposed fluid motion. Thus, in theory at

least, it should be possible to discard equation (1) and replace h by (k/Y).

The essence of Nusselt's approach to the problem lies precisely in this transformation of h into (k/Y). Jakob[14] has given the original Nusselt derivation in detail. Summarized here are the equations which embody Nusselt's key assumptions.

Vertical Tubes: 1. Laminar flow of condensate is assumed. Thus equation (2) above is applicable.

$$dq' = \frac{k}{Y}(\Delta T)\, dz \tag{3}$$

2. The assumptions that—(a) the vapor is virtually at rest; (b) the liquid film properties can be evaluated at some constant average temperature; (c) the inertia and viscous forces of the condensate are in mechanical equilibrium; lead to a velocity distribution equation, in terms of condensate loading, Γ

$$\Gamma = \rho^2 \frac{g\, Y^3}{3\mu} \tag{4}$$

Combination of equation (4), which gives the condensing rate in hydrodynamic terms, with the differential form of the Fourier equation (3), leads to the expressions

$$h_{local} = \left(\frac{k^3 g \rho^2 \lambda}{4\mu Z \Delta T}\right)^{1/4}$$

$$= 0.706 \left(\frac{k^3 g \rho^2 \lambda}{\mu Z \Delta T}\right)^{1/4} \tag{5}$$

and $$h_m = \frac{4}{3}\left(\frac{k^3 g \rho^2 \lambda}{4\mu L \Delta T}\right)^{1/4}$$

$$= 0.943 \left(\frac{k^3 g \rho^2 \lambda}{\mu L \Delta t}\right)^{1/4} \tag{6}$$

Kirkbride[23] rearranged the Nusselt equations into a form with dimensionless moduli, one of which, $(4\Gamma_L/\mu)$, can be regarded as a Reynolds' number for a vertically falling condensate film:

$$h_m \left(\frac{\mu^2}{k^3 \rho^2 g}\right)^{1/3} = 1.47 \left(\frac{4\Gamma_L}{\mu}\right)^{-1/3} \tag{7}$$

Horizontal Tubes: Making use of the same assumptions enumerated above for the case of vertical tubes, Nusselt arrived at the solution

$$h_m = \frac{k}{\left(\frac{4}{3}B\right)^{1/4}\pi} \int_0^{3/4\,(3.428)^*} \frac{d\Phi}{\Phi}$$

$$= \frac{k}{B^{\frac{1}{4}}\pi}\,(3.428)^{3/4} \tag{8}$$

where $B = \frac{3\mu k r \Delta T}{\delta^2 \lambda}$

= a constant by virtue of assumptions (1) and (2) above.

and $\Phi = \int_0^{\phi} \sin^{1/3}\phi\, d\phi$

* the value of the upper limit, 3.428, is arrived at by numerical evaluation of the integral

$$\frac{4}{3}\int_0^{\pi} \sin^{1/3}\phi\, d\phi = 3.428$$

Rearrangement yields the familiar Nusselt form

$$h_m = 0.725 \left(\frac{k^3 g \rho^2 \lambda}{\mu D \Delta T}\right)^{1/4} \tag{9}$$

Nusselt's analysis for several horizontal tubes arranged in a vertical bank utilizes the same assumptions noted above, and in addition, it was assumed that—

3. The effect of the inertia forces of the descending condensate film on the laminar velocity distribution is negligible. Thus, "rippling" is considered to be a negligible effect in reducing condensate film thickness.

4. The temperature difference, $\Delta T = Ts - Tw$, is assumed to be the same for each and every tube in the bank. This is a key assumption, and is indispensable in the development of later correlations suggested by Katz.[16] Peck and Reddie,[28] and Bromley[6] showed that in the case of a **single** tube, Nusselt's assumption of a constant value of ΔT leads to insignificant deviations from the correct equations. It is reasonable to expect that this would hold true for a multitube condenser.

Utilizing these assumptions, Nusselt evaluated the average film coefficient for the *Nth* tube in the bank as

$$h_N = \frac{k}{B^{\frac{1}{4}}\pi} \int_{(N-1)\,(3.428)}^{3.428N} \frac{3/4\, d\Phi}{\Phi^{1/4}}$$

$$= \frac{k}{B^{\frac{1}{4}}\pi}\left[(3.428N)^{3/4} - (N\text{-}1)^{3/4}\,(3.428)^{3/4}\right] \tag{10}$$

where $\Phi = (N\text{-}1)\ 3.428 + \frac{4}{3}\int_0^{\phi} \sin^{1/3}\phi\, d\phi$

For N = 1 (the top-most tube), the value of the coefficient is

$$h_1 = \frac{k}{B^{\frac{1}{4}}\pi}\,(3.428)^{3/4} \tag{11}$$

From equations (10) and (11), the ratio of local coefficients is

$$h_N/h_1 = N^{3/4} - (N\text{-}1)^{3/4} \tag{12}$$

McAdams[24] considers this the key equation in the derivation. Thus, in order to determine the average coefficient for the entire bank of N-tubes, equation (12) is utilized as follows:

$$h_{N\text{-tubes}} = \sum_{N=1}^{N=N} \frac{q'_N}{\pi r N \Delta T}$$

$$= \frac{1}{N}\sum_{N=1}^{N=N} h_N \tag{13}$$

Combining equations (12) and (13);—

$$h_{N\text{-tubes}} = h_m =$$

$$\frac{h_1 + (2^{3/4} - 1)\, h_1 + (3^{3/4} - 2^{3/4})\, h_1 + \ldots [N^{3/4} - (N-1)^{3/4}]h_1}{N}$$

$$= \frac{h_1}{N^{3/4}} \tag{14}$$

Thus equation (9) generalizes to

$$h_m = 0.725 \left(\frac{k^3 g \rho^2 \lambda}{\mu N D \Delta T}\right)^{1/4} \tag{15}$$

Following a procedure analogous to that for a vertical tube, Kirkbride's[23] transformation for a horizontal tube leads to

$$h_m \left(\frac{\mu^2}{k^3 \rho^2 g}\right)^{1/3} = 1.51 \left(\frac{4\Gamma_d}{\mu}\right)^{-1/3} \tag{16}$$

COMPARISON OF NUSSELT'S THEORY WITH EXPERIMENTAL RESULTS

A few of the reasons for deviations between theory and experiment are:

1. Mixed condensation, (dropwise and filmwise), in the case of **steam,** will result in a better over-all performance than occurs according to the film theory.

2. Turbulence of the film has a similar effect. Kirkbride[22] has analyzed the problem from the standpoint of the Reynolds' number of the condensate film. Where $4\Gamma_L/\mu$ exceeds 1,800, an entirely different relationship prevails.

When condensing vapors **inside** vertical tubes, frictional drag of a relatively high vapor velocity can induce turbulence at even lower Reynolds' numbers (circa 240). The interested reader is referred to the excellent discussion of Colburn and Carpenter.[7]

3. The formation of liquid "ripples" may disturb the continuity of the viscous condensate film. Short and Brown's[34] experimental results indicate that surface tension probably plays some role in determining the effect of rippling on the film. Kern[19] has given a good qualitative description of the effect of "continuous stream points" rather than the continuous condensate sheet drainage postulated by Nusselt. Katz[18] and his co-workers have postulated a quantitative approach to this problem, and we will discuss this below in connection with our equations.

With this discussion of the reasons for the existence of deviations in mind, we will discuss the recommended design equations, based on the experimental modifications of the Nusselt theory.

RECOMMENDED DESIGN EQUATIONS

Vertical Tubes: The data average 28 percent higher than equation (7). The recommended relation,[24] therefore, is

$$h_m\left(\frac{\mu^2}{k^3\rho^2 g}\right)^{1/3} = 1.88\left(\frac{4\Gamma_L}{\mu}\right)^{-1/3} \qquad (17)$$

Rewritten, as a dimensional equation, employing convenient units, as

$$\left.\begin{aligned} h_m &= \frac{1.036\times 10^4\psi(t_f)}{\Gamma^{1/3}} \\ &= \frac{\overline{\Psi}(t_f)}{\Gamma^{1/3}} \end{aligned}\right\} \qquad (18)$$

$$\text{where } \psi(t_f) = k_f\left(\frac{S_f^2}{Z_f}\right)^{1/3} \qquad (19)$$

The condensate loading, Γ, is evaluated as

$$\Gamma = \frac{12}{\pi}\frac{W}{XD} \qquad (20)$$

Equation (18) is restricted to

$$\Gamma/Z_f \leqq 1090 \qquad (21)$$

Note that when equation (18) is employed for vapors condensing inside tubes, then D = Di in equation (20). To convert the resulting coefficient to the outside tube surface, the final result must be multiplied by D_i/D_o, where D_o = outside tube diameter. For condensation outside a tube bundle, D_o is employed and no correction is necessary.

Horizontal Tubes: Rewriting equation (16) in a manner similar to equation (18) as

$$h_m = \frac{8.33\times 10^3\psi(t_f)}{\Gamma^{1/3}} \qquad (22)$$

where $\psi(t_f)$ is defined by equation (19).

The evaluation of Γ poses a problem in ordinary shell and tube exchangers. The literature, which is clear enough on the application of equation (15) to a rectangular bundle, is utterly confusing with respect to ordinary circular shell and tube exchangers. With respect to equation (16), the situation is even more obscure.

Katz[16] approached this problem on a sound theoretical basis, and we shall employ his equations as a starting point in developing a method of evaluating the condensate loading, Γ, for a circular shell multitube condenser.

In employing equation (15), Katz suggests that an average value of $N(N_a)$ be evaluated as

$$N_a = \left(\frac{N_1 + N_2 + N_3 + \ldots . N_n}{N_1^{3/4} + N_2^{3/4} + N_3^{3/4} + \ldots . N_n^{3/4}}\right)^4$$

$$= \left(\frac{\Sigma N_n}{\Sigma N_n^{3/4}}\right)^4 \qquad (23)$$

Subscripts 1, 2, 3, etc., refer to individual rows and N is the number of tubes in each row. Although Katz, in the reference cited, does not detail the proof, it is fairly easy to show that assumption 4 above (under basic Nusselt assumptions for temperature difference) is the key assumption.

If **Δt is assumed constant throughout,** then

$$h_n = \frac{C}{N_n^{1/4}} \qquad (24)$$

where C is a constant, h_n denotes the average coefficient for the n^{th} vertical bank, and N_n = the number of horizontal tubes in the n^{th} vertical bank.

An average h for the entire bundle is then necessarily defined from equation (24) as

$$h_m = \frac{h_n N_n^{1/4}}{N_a^{1/4}} \qquad (25)$$

$$\text{now } q_{total} = h_m A_{total}\,\Delta t \qquad (26)$$

$$\text{and } q_{n\,th\,row} = h_n\frac{N_n}{\Sigma N_n}A_{total}\,\Delta t \qquad (27)$$

Therefore,

$$\frac{q_{n\,th\,row}}{q_{total}} = \frac{h_n}{h_m}\,\frac{N_n}{\Sigma N_n} \qquad (28)$$

Also,

$$\Sigma\left(\frac{q_{n\,th\,row}}{q_{total}}\right) = 1.0 = \frac{1}{h_m\Sigma N_n}\Sigma h_n N_n$$

$$\text{or } h_m\Sigma N_n = \Sigma h_n N_n \qquad (29)$$

From equation (25)

$$h_n N_n = N_n^{3/4} h_m N_a^{1/4}$$

$$\text{or } \Sigma h_n N_n = h_m N_a^{1/4} \Sigma N_n^{3/4} \quad (30)$$

Combining equations (29) and (30),

$$h_m \Sigma N_n = h_m N_a^{1/4} \Sigma N_n^{3/4} \quad (31)$$

Solving equation (31) for N_a yields equation (23).

Thus, Katz's equation is in no way empirical, as the derivation above clearly indicates.

Unfortunately, it is a tedious affair to apply equation (23) to a fair sized bundle. Realizing this fact, Katz, Young and Balekjian[18] suggested the following empirical approximations of equation (23):

$$\left.\begin{aligned} N_a &= 0.815\, X^{0.52} \text{ for square pitch} \\ N_a &= 0.40\, X^{0.54} \text{ for triangular pitch} \end{aligned}\right\} \quad (32)$$

Lacking any expressions for the industrially important cases of horizontal apex triangular pitch and rotated square pitch, the author decided to correlate actual tube-fields for all four orientations. Figures 1 and 2 show the resulting correlations. In equational form, these curves are represented by

$$\left.\begin{aligned} N_a &= 0.815\, X^{0.52} \text{ for square pitch} \\ N_a &= 0.481\, X^{0.505} \text{ for triangular pitch} \\ N_a &= 0.97\, X^{0.481} \text{ for horizontal apex triangular pitch} \\ N_a &= 0.730\, X^{0.482} \text{ for rotated square pitch} \end{aligned}\right\} \quad (33)$$

Our equation for square pitch checks the recommendation of Katz et al precisely, but differs slightly from that proposed for triangular pitch.

We are now ready to derive an expression for Γ. Using equation (15) as a starting point, we write

$$h_m = 0.725 \left(\frac{k^3\rho^2 g\lambda}{\mu N_a D \Delta T}\right)^{1/4} \quad (15)$$

where N_a is defined by equation (33).
By definition,

$$h_m = \frac{q}{A\Delta T} = \frac{\lambda W}{L\pi D X \Delta T} \quad (34)$$

Writing an equation of definition;

$$X = N_a n_s \quad (35)$$

The procedure of determining an average value of N_a in a circular shell is equivalent, geometrically, to transforming a circular tube field into its equivalent rectangular field. (Of course, the evaluation of N_a is also contingent upon the boundary conditions postulated by Nusselt.) It follows, then, immediately from equation (35) that n_s represents the **equivalent number of condensate streams** in this transformation.

Combining equations (15), (34) and (35) yields the expression

$$h_m = 0.725 \left(\frac{k^3\rho^2 g}{\mu}\right)^{1/4} \left(\frac{\lambda W}{L\pi D X \Delta T}\right)^{1/4} \left(\frac{\pi L n_s}{W}\right)^{1/4} \quad (36)$$

From the definition of the individual terms, the condensate loading for a horizontal bundle is

$$\Gamma = \frac{W}{L n_s} \quad (37)$$

Combining equations (34), (36) and (37);

$$h_m^{3/4} = 0.725 \left(\frac{k^3\rho^2 g}{\mu}\right)^{1/4} \left(\frac{\pi}{\Gamma}\right)^{1/4} \quad (38)$$

which rearranges to

$$h_m \left(\frac{\mu^2}{k^3\rho^2 g}\right)^{1/3} = 1.51 \left(\frac{4\Gamma}{\mu}\right)^{-1/3} \quad (39)$$

This is identical in form with Kirkbride's equation (16) for a **single** horizontal tube. Γ, the condensate loading, is evaluated from equation (37), and n_s in the latter is evaluated from equation (35). Combination of equations (35) and (33) yields the equations for the equivalent number of condensate streams for the various tube-field orientations:

$$\left.\begin{aligned} n_s &= 1.288\, X^{0.480} \text{ for square pitch} \\ n_s &= 2.08\, X^{0.495} \text{ for triangular pitch} \\ n_s &= 1.022\, X^{0.519} \text{ for horizontal apex triangular pitch} \\ n_s &= 1.370\, X^{0.518} \text{ for rotated square pitch} \end{aligned}\right\} \quad (40)$$

Figure 3 is a nomogram representing the equations (40).

A modification of equation (15) to account for experimental deviations from Nusselt's equation, discussed under Comparison of Nusselt's Theory with Experimental Results—3 above, has been suggested by Katz.[17] Based on the bare-tube data of Young and Wohlenburg,[40] and the finned-tube data of Katz and Geist,[15] equation (15) is modified to

$$h_m = 0.725\, C_N \left(\frac{k^3 g\rho^2\lambda}{\mu N D \Delta T}\right)^{1/4} \quad (41)$$

log C_N is correlated[17] as a linear function of log N_a, i.e.,

$$C_N = b N_a^{\,m} \quad (42)$$

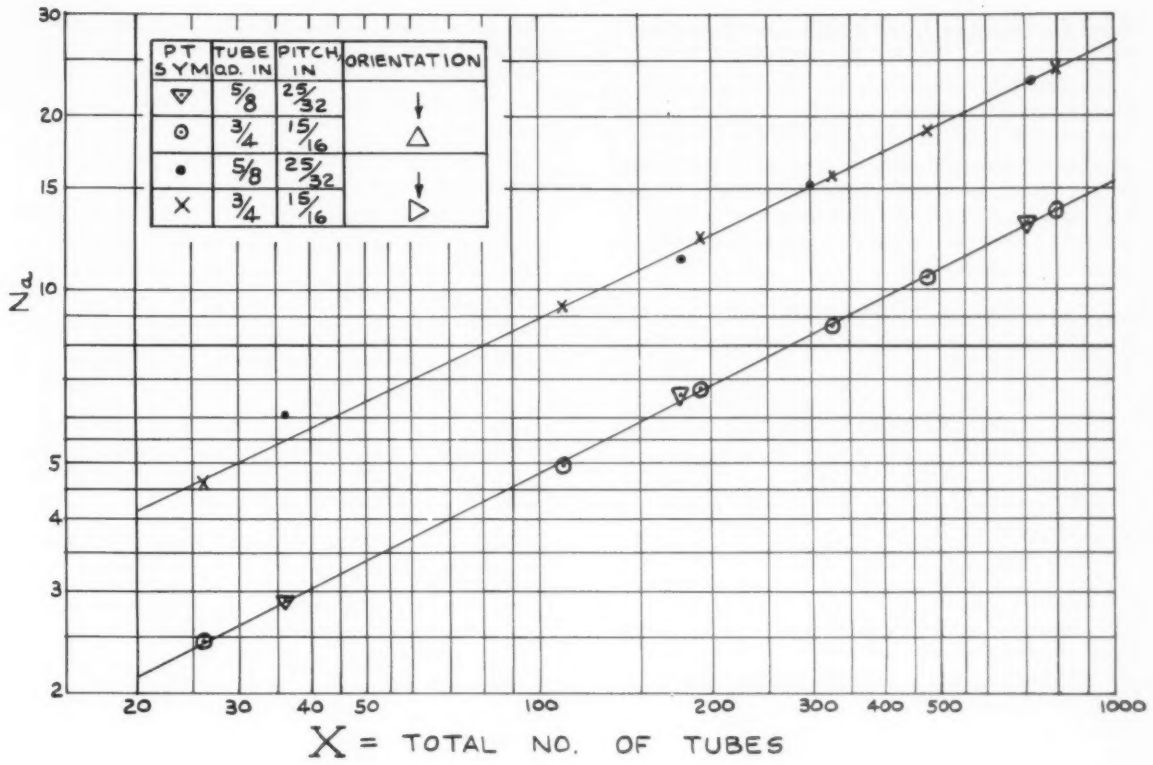
where the constants b and m are peculiar to the vapor under consideration. Young, Katz et al[17] have made the reasonable assumption that data obtained for the C_N factor for a particular type of organic compound can be extended to related compounds.

The modications of equations (39) and (22) to include the C_N — factor are

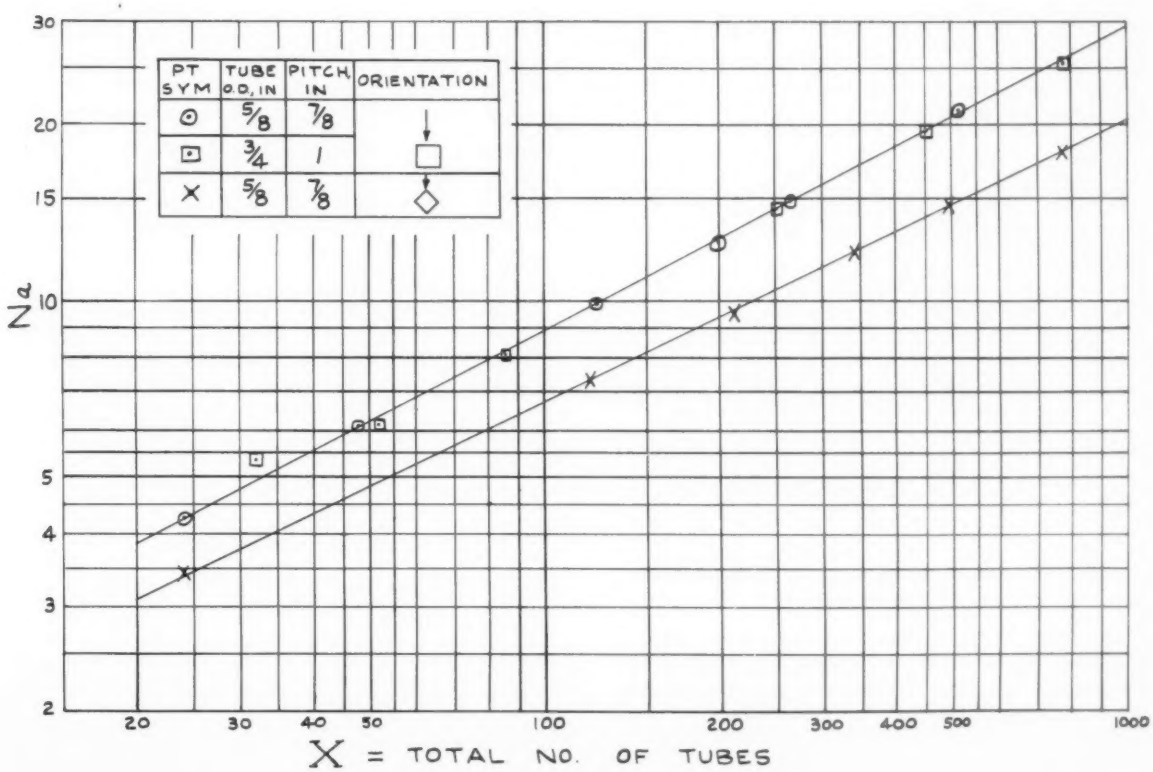
$$h_m \left(\frac{\mu^2}{k^3\rho^2 g}\right)^{1/3} = 1.51\, C_N^{4/3} \left(\frac{4\Gamma}{\mu}\right)^{-1/3} \quad (43)$$

$$\text{and } h_m = \frac{8.33 \times 10^3\, C_N^{4/3} \psi(t_f)}{\Gamma^{1/3}} \quad (44)$$

Figure 6 represents the data collected, thus far, in nomographic form.[39] In order to use this nomogram, it is first necessary to evaluate N_a. Figure 3 is employed to evaluate n_s, the number of condensate streams, and then equation (35) is solved for N_a.



FIGURES 1 and 2—Figure 1 (above) and Figure 2 (below) gives correlations for actual tube-fields for four different orientations. From these two charts the average number of tubes for a circular shell multitube condenser can be picked off.



As pointed out above, it would not be unreasonable to apply the data for acetone to other ketones, the data for n-butane to other hydrocarbons, etc. It is unfortunate that the very importtant vapor, steam, has not been correlated. Katz and Geist[15] rejected their data on condensing steam because it proved impossible to eliminate dropwise condensation under the experimental conditions.

Horizontal Extended Surface Tubes: Balekjian and Young[4] recommend a modication of equation (41) for extended surface tubes;

$$h_m = 0.725\, C_N \left(\frac{k^3 g^2 \rho^2 \lambda}{\mu N D_{eq.} \Delta T}\right)^{1/4} \qquad (45)$$

The terms h_m and $D_{eq.}$ are functions of the weighted fin efficiency and geometry of the extended surface tube or fintube.

By definition

$$\left(\frac{1}{D_{eq}}\right)^{1/4} = \frac{a_r}{a_o}\frac{1}{D_r^{1/4}} + 1.30\eta\,\frac{a_f}{a_o}\left(\frac{1}{L_h}\right)^{1/4} \qquad (46)$$

where $D_{eq.}$=equivalent outside diameter defined by the above equation.

Also

$$h_m = \frac{q}{A_o \Delta T} = \frac{\lambda W}{L a_o X \Delta T} \qquad (47)$$

Substituting in equation (45),

$$h_m = 0.725\, C_N \left(\frac{k^3\rho^2 g}{\mu}\right)^{1/4}\left(\frac{\lambda W}{L a_o N n_s \Delta T}\right)^{1/4}\left(\frac{1}{D_{eq.}}\right)^{1/4}\left(\frac{n_s L a_o}{W}\right)^{1/4} \qquad (48)$$

Utilizing the defining equation (37) and simplifying, yields the expression

$$h_m \left(\frac{\mu^2}{k^3\rho^2 g}\right)^{1/3} = 1.03\, C_N^{4/3}\left(\frac{a_o}{D_{eq.}}\right)^{1/3}\left(\frac{4\Gamma}{\mu}\right)^{-1/3} \qquad (49)$$

Comparison of equations (39) and (49) gives the relationship

$$\frac{h_m\ (\text{fintube})}{h_m\ (\text{baretube})} = 0.68\left(\frac{a_o}{D_{eq.}}\right)^{1/3} \qquad (50)$$

For the typical fintubes,[36] $a_f/a_o = 0.80$ and $a_r/a_o = 0.20$. For this particular fintube, then, equation (50) simplifies to

$$\frac{h_m\ (\text{fintube})}{h_m\ (\text{baretube})} = 0.68\, a_o^{1/3}\left(\frac{0.20}{D_r^{1/4}} + \frac{1.04\eta}{L_h^{1/4}}\right)^{4/3} \qquad (51)$$

NOMOGRAPHIC SOLUTION OF THE DESIGN EQUATIONS

Donohue[9] observed that the tube loading form of the Nusselt equation was more easily handled in design. In addition, he observed that the physical property factor, designated by $\psi(t_f)$ in this article, was nearly constant over wide temperature ranges for hydrocarbons. Recent improvements in the underlying theory and the technique of measurement of thermal conductivity[12, 27, 31, 32, 38] prompted this author to reinvestigate the hydrocarbon compounds. In addition, the physical property factors for other organic compounds were examined.

In the Appendix, the references consulted in evaluating $\psi(t_f)$ are enumerated.

Inspection of equations (17) and (39) indicates that they are identical in form except for the constant. As a consequence of this fact, a nomograph drawn for vertical tubes can be used to determine a coefficient for horizontal tubes provided:

1. The resulting value of h_m is multiplied by $(1.51/1.88) = 0.8$, in order to account for the difference in constants,

2. Figure 3 and equation (37) are used for evaluating Γ for horizontal bundles, (equation (20) is employed for vertical tubes).

3. Figure 6 is used to effect the correction indicated by equation (44).

In addition, equation (51) can be employed to correct the result for fintubes.

As it is convenient to employ logarithmically calibrated scales for nomographing equation (18), a correlation of log $\psi(t_f)$ with t_f was investigated. All of the compounds studied could be correlated by one, or at the most, two straight lines over the indicated temperature range. Figures 4A and 4B were constructed on this basis.

In the particular case of the hydrocarbons, the results obtained indicate lower values of $\psi(t_f)$ than those used by Donohue. This will tend to be compensated somewhat by the turbulence correction factor (Figure 6). As a specific instance, Donohue gives $\bar{\psi}(t_f) = 748$ for n-pentane at 250 F. Our nomograph, Figure 4B, gives $\bar{\psi}(t_f) = 520$ for a vertical tube. For horizontal tube banks, this would decrease to $0.8 \times 520 = 416$. On the other hand, at 50 F., Donohue's value is 780 and Figure 4B yields $830 \times 0.8 = 664$, a somewhat closer agreement. The discrepancies are mostly due to the new thermal conductivity values employed in this article.

Steam occupies a unique place in process heat transfer; therefore, a separate nomograph, Figure 5, was constructed. Devore[8] observed that improved thermal conductivity data for water made it necessary to abandon the well known alignment chart of Chilton, Genereaux and Vernon. The fact that the physical property factor goes through a maximum is reflected in the "double" scale of Figure 5.

ILLUSTRATIVE PROBLEMS

Organic Vapor Condenser: 15,000 lb./hr. of n-pentane vapor, saturated at 25 psia, is to be condensed. Cooling tower water in at 85 F. and out at 105 F. is available. Fouling factors of 0.002 for the C. W. and 0.001 for the vapor are specified. ¾" O.D. #14 BWG. steel tubes, 16'-0" long, should be used. A split-ring floating head exchanger is desired. Three alternative designs are to be investigated:

1. Vertical baretube
2. Horizontal baretube
3. Horizontal fintube

Solution for Vertical Baretube: Using the vapor pressure nomograph in Nelson,[25] the saturation temperature of n-pentane, corresponding to 25 psia, is 126 F. From the Scheibel-Jenny Nomographs,[33] the latent heat is 278-129 = 149 Btu/pound.

1. Heat and Material Balances:

$$q = 15{,}000 \times 149 = 2{,}236{,}000 \text{ Btu/hr.}$$

$$w = \frac{2{,}236{,}000}{20.0 \times 1.00} = 111{,}800 \text{ pounds cooling water per hr.}$$

$$\text{GPM of Cooling Water} = \frac{111{,}800}{500} = 224 \text{ GPM}$$

2. Temperature Differences:

Hot Fluid	Cold Fluid	Temp. Diff.
$T_a = 126$	$t_a = 95$	$T_a - t_a = 31$
$T_1 = 126$	$t_2 = 105$	$\Delta t_h = 21$
$T_2 = 126$	$t_1 = 85$	$\Delta t_c = 41$
	$t_2 - t_1 = 20$	$\Delta t_c - \Delta t_h = 20$

$$\Delta t_M = \frac{\Delta t_c - \Delta t_h}{\ln \frac{\Delta t_c}{\Delta t_h}} = \frac{20}{\ln \frac{41}{21}} = 29.9 \text{ degrees}$$

3. Set-Up of Exchanger:

As a first trial, assume $U_D = 80$. Then

$$A = \frac{2{,}236{,}000}{80 \times 29.9} = 933 \text{ square feet}$$

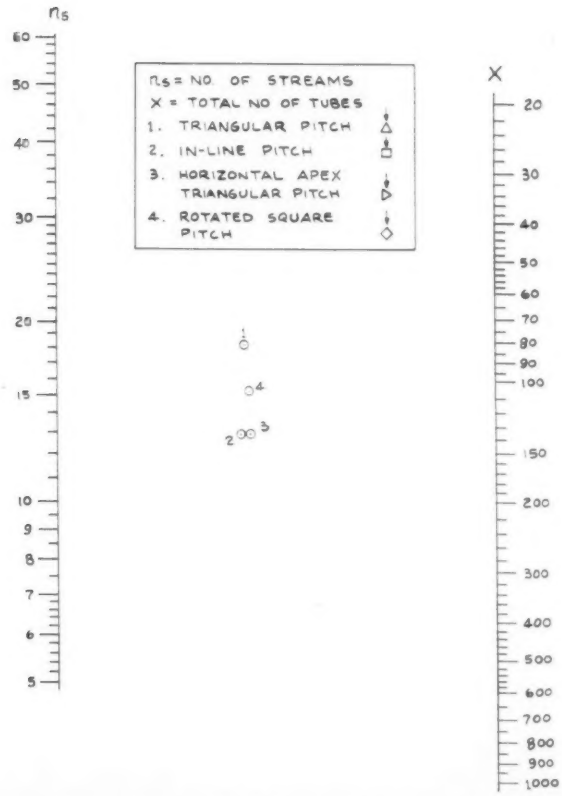


FIGURE 3—Gives the number of condensate streams in a horizontal bundle.

$$\text{No. of tubes required} = \frac{933}{16.0 \times 0.1963} = 297$$

Using Kern's[20] tube counts, try 314 tubes with 4 tube passes in a 21¼" I.D. shell. The tubes are on 15/16" — Δ pitch. This unit will have a surface of 986 square feet.

4. Rating of Exchanger: Cooling Water Film—

$$V = \frac{224 \times 4}{314 \times 0.835} = 3.42 \text{ fps}$$

Using the Eagle and Ferguson data,[11]

$$h_{io} = 880 \times 1.012 \times \frac{0.584}{0.750} = 694$$

Condensate Film—Assume $\Delta T = 24$ degrees

$$t_f = 126 - 12 = 114 \text{ F.}$$

From Lohrenz's[28] nomograph, $Z_f = 0.223$ Cp.

From equation (20), the condensate loading is

$$\Gamma = \frac{12}{\pi} \times \frac{15{,}000}{314 \times 0.750} = 243.8\#/\text{hr.-ft.}$$

$$\Gamma/Z_f = \frac{243.8}{0.223} = 1090$$

From inspection of equation (21) it can be seen that this unit is operating on the borderline of turbulence, but equation (18) is still applicable.

From Figure 4B, using point 5, we obtain $h_m = 122$

$$\text{at } \left\{ \begin{matrix} t_f = 114 \text{ F.} \\ \Gamma = 243.8\#/\text{hr.-ft.} \end{matrix} \right\}$$

Tube-Wall Resistance—This is calculated as

$$h_{tw} = \frac{2 \times 12}{0.750 \ln \frac{0.750}{0.584}} \times 26 = 3330$$

Over-all Clean Coefficient—

$$1/h_{io} = 1/694 = .00144$$
$$1/h_{tw} = 1/3330 = .00030$$
$$1/h_m = 1/122 = .00820$$
$$1/U_c = .00994$$

Check on Assumed ΔT[20]—

$$\Delta T = \frac{1/h_m}{1/U_c}(T_a - t_a) = \frac{820}{994} \times 31 = 25.6' \sim 24' \text{ assumed.}$$

Over-all Fouled Coefficient—

$$1/U_c = .00994$$
$$\text{total ff} = .00300$$
$$1/U_D = .01294, \text{ whence } U_D = 77.2$$

Required Surface—

$$A = \frac{2{,}236{,}000}{77.2 \times 29.9} = 968$$

$$L = \frac{968}{314 \times 0.1963} = 15.70 \text{ ft.} < 16 \text{ ft. used}$$

The unit is satisfactory.

Solution for Horizontal Baretube: Steps (1) and (2) are the same as for vertical baretubes above.

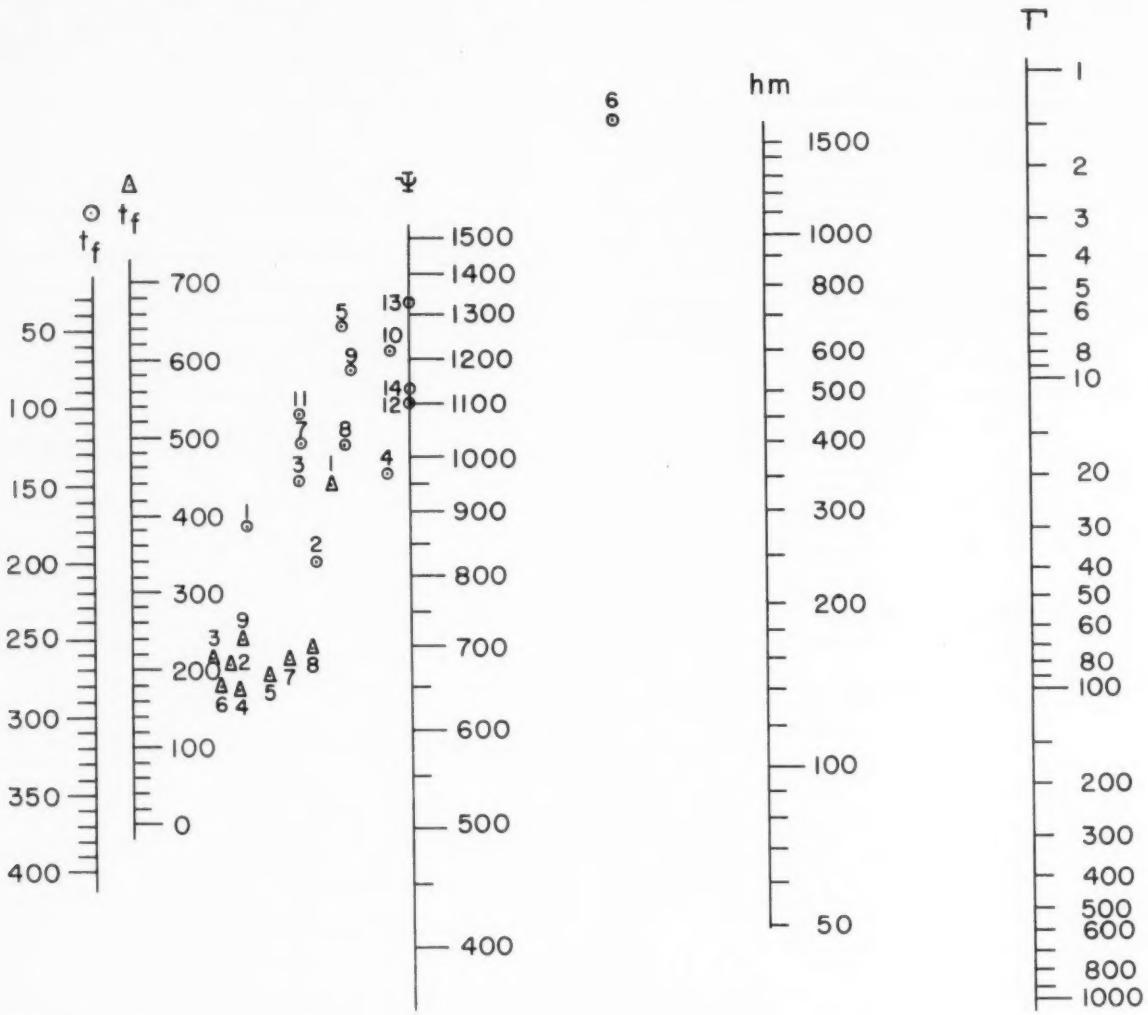


FIGURE 4—These condensate film coefficients for vertical surfaces are restricted to $\Gamma/Z_t \leq 1090$. To obtain theoretical h_m for horizontal tubes, use the above nomogram and multiply result by 0.8.

Substance	Range, °F	Point
n-Propanol	32 - 122	①
n-Propanol	122 - 380	②
Ethanol	32 - 158	③
Ethanol	158 - 377	④
Methanol	32 - 172	⑤
Methanol	172 - 365	⑥
CCl_4	32 - 118	⑦
CCl_4	118 - 390	⑧
$CHCl_3$	32 - 154	⑨
$CHCl_3$	154 - 320	⑩
Benzene	32 - 114	⑪
Benzene	114 - 383	⑫
Acetone	32 - 300	⑬

Substance	Range, °F	Point
Diethyl Ether	32 - 257	⑭
Eutectic Mixture Of Diphenyl And Diphenyl Oxide	500 - 700	△
Dichlorodifluoromethane	32 - 140	△
Chlorodifluoromethane	0 - 120	△
sym-Dichlorotetrafluoroethane	32 - 175	△
n-Pentane	50 - 150	△
n-Pentane	150 - 250	△
n-Hexane	50 - 218	△
n-Hexane	218 - 350	△
n-Octane	50 - 250	△
n-Octane	250 - 400	△

Set-up of Exchanger—We can expect a much higher coefficient for a horizontal unit of the same length. As a first trial, assume U = 140. Then

$$A = \frac{2{,}236{,}000}{140 \times 29.9} = 533 \text{ square feet}$$

$$\text{Number of tubes required} = \frac{533}{16.0 \times 0.1963} = 169.4 \sim 170 \text{ tubes.}$$

Using Kern's tube counts, we try 166 tubes with 2 tube passes in a 17¼" I.D. shell (this is not a full count). Again, the tubes are on 15/16" — Δ pitch. This unit will have a surface of 521 square feet.

Rating of Exchanger: Cooling Water Film:

$$V = \frac{224}{83 \times 0.835} = 3.23 \text{ fps}$$

$$h_{io} = 850 \times 1.012 \times \frac{0.584}{0.750} = 670$$

Condensate Film—Again assume $\Delta T = 24°$

Then $t_f = 114$ F. and $Z_f = 0.223$ c.p.

From Figure 3, $n_S = 26.2$ streams
Using equation (37),

$$\Gamma = \frac{15{,}000}{26.2 \times 16} = 35.8\#/\text{hr. ft.}$$

Using equation (35),

$$N_a = \frac{166}{26.2} = 6.33$$

Using the point for *n*-butane on Figure 6,

$$C_n^{4/3} = 1.75$$

From Figure 4B, the value of h_{ni} is now obtained

$$h_m = 230 \times 0.8 \times 1.75 = 322$$

Clean Over-all Coefficient—

$1/h_{io}$	$= 1/670 = .00149$
$1/h_{tw}$	$= 1/3330 = .00030$
$1/h_m$	$= 1/322 = .00310$
$1/U_c$	$= .00489$

Check on Assumed ΔT—

$$\Delta T = \frac{310}{489} \times 31 = 19.70° \sim 24° \text{ assumed.}$$

Over-all Fouled Coefficient—

$1/U_c = .00489$
total ff $= .00300$
$1/U_D = .00789$, whence $U_D = 127.0$

Required Surface—

$$A = \frac{2{,}236{,}000}{127.0 \times 29.9} = 588 \text{ square feet} > 521 \text{ square feet assumed.}$$

It is unnecessary to re-rate the unit. We simply multiply our previous tube count by the area ratio, i.e.—

$$\text{Number of tubes required} = \frac{588}{521} \times 166 = 187.1 \sim 188 \text{ tubes.}$$

From Kern's tables, it is evident that a 17¼" I.D. shell will still suffice. The surface of the unit employed is

$$A = 16.0 \times 0.1963 \times 188 = 590 \text{ square feet}$$

Solution for Horizontal Fintube: Steps (1) and (2) are the same as for vertical baretubes above.

Set-up of Exchanger: A coefficient somewhat lower than the 127.0 calculated for horizontal baretubes must be expected. This is due to two factors: (1) a high fouling factor for the cooling water must be multiplied by an unfavorable area ratio, and (2) the efficiency of the fin.

As a first trial, assume $U_D = 80$

$$A = \frac{2{,}236{,}000}{80 \times 29.9} = 933 \text{ square feet}$$

The fintube[37] selected has a ¾" O.D. nominal fin, a ⅝" root diameter, and 19 fins per inch. The value of a_o for this tube is 0.496 square feet per foot.

$$\text{Number of tubes required} = \frac{933}{15.5 \times 0.496} = 121.2 \sim 122 \text{ tubes.}$$

Using Kern's tube counts, we try 122 tubes on 15/16" — Δ pitch, with 2 tube passes in a 15¼" I.D. shell (this is not a full tube count). This unit will have a surface of (allowing for 0.5 foot of plain ends)

$$A_o = 15.5 \times 0.496 \times 122 = 938 \text{ square feet}$$

Rating of Exchanger: Cooling Water Film:

$$V = \frac{224 \times 1.94}{61} = 7.12 \text{ fps}$$

$$h_{io} = \frac{1590 \times 1.063}{4.14} = 408$$

Condensate Film: Again assume $\Delta T = 24$ degrees.

Then $t_f = 114$ F. and $Z_f = 0.233$ c.p.

From Figure 3, $n_S = 22.5$ streams

Using equation (37),

$$\Gamma = \frac{15{,}000}{22.5 \times 15.5} = 43.0\#/\text{hr. ft.}$$

Using equation (35),

$$N_a = \frac{122}{22.5} = 5.42$$

Using the point for *n*-butane on Figure 6,

$$C_N^{4/3} = 1.65$$

From Figure 4B, the value of h_m (baretube) is now obtained as

$$h_m \text{ (baretube)} = 220 \times 0.8 \times 1.65 = 290$$

It is now necessary to use equation (51) to arrive at the coefficient on the finside. Using $h_m = 290$ as a first approximation in arriving at η, from the booklet,[26] $\eta = 0.79$. From the same reference, $D_r^{1/4} = 0.478$ and $L_h^{1/4} = 0.345$. Thus

$$\frac{h_m \text{ (fintube)}}{h_m \text{ (baretube)}} = 0.68\ (0.496)^{1/3} \left(\frac{0.20}{0.478} + \frac{1.04 \times 0.79}{0.345} \right)^{4/3}$$

$$= 0.68 \times 0.791 \times 3.94 = 2.12$$

$$\text{Thus } h_m \text{ (fintube)} = 290 \times 2.12 = 615$$

Trying now for a value of h_m intermediate to the 290 assumed and the 615 calculated, say $h_m = 500$, $\eta = 0.71$. Adjusting the above calculation,

$$h_m \text{ (fintube)} = 615 \times \frac{3.50}{3.94} = 546$$

This is close enough to the assumed value so that no further adjustment is necessary.

How to Design Multitube Condensers...

Tube Wall Resistance: This is calculated as

$$h_{tw} = \frac{2\pi}{0.496 \ln \frac{0.624}{0.458}} \times 26 = 1067$$

Over-all Clean Coefficient:

$$\begin{array}{rl} 1/h_{io} & = 1/408 = .00245 \\ 1/h_{tw} & = 1/1067 = .00094 \\ 1/h_m & = 1/546 = .00183 \\ \hline 1/U_c & = .00422 \end{array}$$

Check on assumed ΔT:

$$\Delta T = \frac{183}{422} \times 31 = 13.44° < 24° \text{ assumed.}$$

This is not, however, worth an adjustment because of the relative insensitivity of $\psi(t_f)$.

Over-all Fouled Coefficients: The fouling factor on the cooling water side must be corrected by the area ratio. Thus

$$\begin{array}{rl} \text{ff of C.W.} = 4.14 \times .002 & = .00828 \\ \text{ff vapor} & = .00100 \\ 1/U_c & = .00422 \\ \hline 1/U_D & = .01350, \text{ whence } U_D = 74.0 \end{array}$$

Required Surface:

$$A_o = \frac{2{,}236{,}000}{74.0 \times 29.9} = 1010 \text{ square feet}$$

As under horizontal baretube above, it is necessary to re-rate the unit. The required tube count is

$$\text{Number of tubes required} = \frac{1010}{938} \times 122 = 131.2, \text{ or say } 132$$

and a 15¼" I.D. shell will still suffice.

The area employed is

$$A_o = 132 \times 0.496 \times 15.5 = 1015 \text{ square feet}$$

SUMMARY OF CALCULATIONS FOR ORGANIC VAPOR CONDENSER

Type of Unit	Shell I.D.	Surface	Est. Cost[21]
Vertical baretube	21¼"	986	$4800
Horizontal baretube	17¼"	590	$3600
Horizontal fintube	15¼"	1015	$3250

The cost comparison above is typical for organic vapors. Had lower fouling factors been specified, the result would have been even more favorable to the fintube design.

Feedwater Heater (Condensation of Steam)—29,000 pounds/hour feed water is to be heated from 102 F. to 200 F. using 2 psig saturated steam. A cleanliness factor of 90 percent is specified. ⅝" O.D. #18 BWG. Admiralty U-tubes are to be used. A horizontal design, with partition seals, is specified.

Solution

Heat and Material Balances:

$$q = 29{,}000\ (200 - 102) = 2{,}840{,}000 \text{ Btu/hr.}$$

$$W = \frac{2{,}840{,}000}{966} = 2940\# \text{ steam/hr.}$$

Temperature Differences:

Hot Fluid	Cold Fluid	Temp. Diff.
$T_a = 218.5$	$t_a = 151$	$T_a - t_a = 67.5$
$T_1 = 218.5$	$t_2 = 200$	$\Delta t_h = 18.5$
$T_2 = 218.5$	$t_1 = 102$	$\Delta t_c = 116.5$
	$t_2 - t_1 = 98$	98.0

$$\Delta t_M = \frac{98.0}{\ln \frac{116.5}{18.5}} = 53.3 \text{ degrees}$$

Set-up of Exchanger: As a first trial, assume $U_D = 600$. Then

$$A = \frac{2{,}840{,}000}{600 \times 53.3} = 88.8 \text{ square feet}$$

Assuming a 16'-0" developed length (for maximum length tubes);

$$\text{Number of U-tubes required} = \frac{88.8}{16 \times 0.1636} = 34$$

A standard 4-pass feedwater heater with 32-$\frac{5}{8}$" O.D. U-tubes on 13/16" — Δ pitch will be tried.

Rating of Exchanger: Feedwater Film:

$$29{,}000/500 = 58 \text{ GPM}$$

$$V = \frac{58}{16 \times 0.678} = 5.35 \text{ fps}$$

Using the Eagle and Ferguson data,

$$h_{io} = 1610 \times 1.033 \times \frac{.527}{.625} = 1400$$

Tube-Wall Resistance—This is calculated as

$$h_{tw} = \frac{2 \times 12}{0.625 \ln \frac{0.625}{0.527}} \times 64.0 = 14{,}400$$

Condensate Film: Assume ΔT = 33°. Then $t_f = 218.5 - 16.5 = 202.0°$ F.

From Figure 3, $n_g = 8.8$ streams for $X = 64$ tubes (because of 4-pass U-tube orientation, horizontal apex triangular pitch is used).

Using equation (37),

$$\Gamma = \frac{2940}{8.8 \times 8} = 41.8\#/\text{hr. ft.}$$

From Figure 5, $h_m = 1720 \times 0.8$ at $\{\Gamma = 41.8\#/\text{hr. ft.}, t_f = 202.0 \text{ F.}\}$

or, $h_m = 1375$

Clean Over-all Coefficient:

$$\begin{array}{rl} 1/h_{io} & = 1/1400 = .000715 \\ 1/h_{tw} & = 1/14400 = .000069 \\ 1/h_m & = 1/1375 = .000727 \\ \hline 1/U_c & = .001511 \end{array}$$

Check on assumed ΔT:

$$\frac{727}{1511} \times 67.5 = 32.4° \sim 33° \text{ assumed.}$$

Over-all Fouled Coefficient:

$$U_c = 1/.001511 = 661$$

$$U_D = 661 \times 0.90 = 595$$

Required Surface:

$$A = \frac{2{,}840{,}000}{595 \times 53.3} = 89.5 \text{ square feet}$$

$$\text{Average developed length required} = \frac{89.5}{32 \times 0.1636} = 17.10 \text{ ft.}$$

By actual computation of individual tube lengths, a maximum developed length of 18'-0" results in an average developed length of 17.40 feet ~ 91.1 square feet of surface.

APPENDIX

References Used in Determining $\psi(t_f)$

Substance	Thermal Conductivity	Specific Gravity	Viscosity
n-Propanol	(31)	(29)	(13)
Ethanol	(31)	(29)	(13)
Methanol	(31)	(29)	(13)
CCl_4	(38)	(30)	(13)
$CHCl_3$	(38)	(30)	(13)
Benzene	(32)	(26)	(13)
Acetone	(32)	(26)	(13)
Diethyl Ether	(32)	(26)	(13)

Eutectic mixture of diphenyl and diphenyl oxide	(38)	(10)	(10)
Dichlorodifluoromethane	(35)	(1)	(5)
Chlorodifluoromethane	(35)	(30)	(5)
sym-Dichlorotetrafluoroethane	(35)	(32)	(32)
n-Pentane	(31)	(26)	(23)
n-Hexane	(31)	(26)	(23)
n-Octane	(31)	(26)	(23)
Water	(2)	(2)	(2)

Notation

Symbol	Quantity	Units
	a. Simple Latin Letter Symbols	
A	Heat transfer surface	square feet
A_o	Total finside heat transfer surface	square feet
a_f	finned portion of finside heat transfer surface per unit length	square feet/foot
a_o	total finside heat transfer surface per unit length	square feet/foot
a_r	root portion of finside heat transfer surface per unit length	square feet/foot
C_N	Turbulence correction factor	———
D	Tube diameter in equations (9) and (15) in equation (20)	feet inches
D_i	inside tube diameter	inches
D_o	outside tube diameter	inches
D_r	finned tube root diameter	feet
$D_{eq.}$	Equivalent diameter of a finned tube used in calculation of condensate film	feet
ff	Fouling factor	$(Btu/hr.\text{-}ft.^2\text{-}F)^{-1}$
g	acceleration of gravity	$feet/hour^2$
h	Film coefficient of heat transfer	$\frac{Btu}{hr.\text{-}ft.^2\text{-}F.}$
h_{io}	Inside film coefficient referred to outside surface	$\frac{Btu}{hr.\text{-}ft.^2\text{-}F.}$
h_m	Mean value of condensate film coefficient	$\frac{Btu}{hr.\text{-}ft.^2\text{-}F.}$
h_{tw}	Equivalent tube wall coefficient	$\frac{Btu}{hr.\text{-}ft.^2\text{-}F.}$
k	Thermal conductivity	$\frac{Btu\text{-}ft.}{hr.\text{-}ft.^2\text{-}F.}$
k_f	Thermal conductivity of condensate film at mean film temperature	$\frac{Btu\text{-}ft.}{hr.\text{-}ft.^2\text{-}F.}$
L	Total tube length	feet
N	Number of horizontal tubes in a vertical row	———
N_a	Average value of N for a circular shell multitube condenser	———
n_s	equivalent number of condensate streams in a horizontal bundle	———
q	Rate of heat flow	$\frac{Btu}{hr.}$
q'	Rate of heat flow per unit width	$\frac{Btu}{hr.\text{-}ft.}$
q'_N	Value of q' for N^{th} tube	$\frac{Btu}{hr.\text{-}ft.}$
r	radius of tube	feet
S_f	Specific gravity of condensate film at mean film temperature	———
T_a	Average hot fluid temperature	°F.
t_a	Average cold fluid temperature	°F.
t_f	Mean condensate film temperature	°F.
U_c	Clean over-all coefficient	$\frac{Btu}{hr.\text{-}ft.^2\text{-}F.}$
U_D	Fouled over-all coefficient	$\frac{Btu}{hr.\text{-}ft.^2\text{-}F.}$

About the Author

Abe Devore is a chief rating engineer for Davis Engineering Corp., Elizabeth, N. J., where he handles the rating of engineers, correlates research and development data, and trains sales engineers in technical aspects of their duties. He has a B.S. degree in chemical engineering from Cooper Union and a M.S. degree in chemical engineering from Brooklyn Polytechnic Institute. Before joining Davis Engineering in 1945, Devore was a chemical engineer with Kellex Corp., working on the Manhattan project. Previously a petroleum inspector with the Inspector of Naval Material, New York, he is a member of AIChE's Heat Transfer division, and the Fuel and Water Heater Manufacturer's Association.

V	velocity	$\frac{feet}{seconds}$
W	Total condensation rate	$\frac{\#\text{-mass}}{hr.}$
X	Total number of tubes	———
Y	Thickness of condensate film	feet
Z_f	Dynamic viscosity at mean film temperature	c.p.
z	Distance below top of vertical condensing surface	feet
	b. Greek and Composite Greek-Latin Symbols	
Γ	Condensate loading	$\frac{\#\text{-mass}}{hr.\text{-}ft.}$
Γ_D	Condensate loading at lowest point of a horizontal tube	$\frac{\#\text{-mass}}{hr.\text{-}ft.}$
Γ_L	Condensate loading at lowest point of a vertical tube	$\frac{\#\text{-mass}}{hr.\text{-}ft.}$
δ	Specific weight of condensate	$\frac{\#\text{-force}}{feet^3}$
ΔT	Temperature difference across the condensate film	F.
Δt	Temperature difference	F.
Δt_c	Cold terminal temperature difference	F.
Δt_h	Hot terminal temperature difference	F.
η	Weighted efficiency of a fintube	———
λ	latent heat of vaporization at saturation temperature	$\frac{Btu}{\#\text{-mass}}$
μ	dynamic viscosity of condensate	$\frac{\#\text{-force-hr.}}{feet^2}$
π	Numerical constant, 3.14.....	———
ρ	Density of condensate	$\frac{\#\text{-mass}}{feet^3}$
ϕ	angle which any radius, r, forms with a vertical line	radians
$\psi(t_f)$	Physical property factor of condensate film, evaluated by equation (19) at mean film temperature	
$\overline{\Psi}(t_f)$	$1.036 \times 10^4 \psi\ (t_f)$	
	c. Operator of Symbols	
Σ	Summation	
d	Differential	

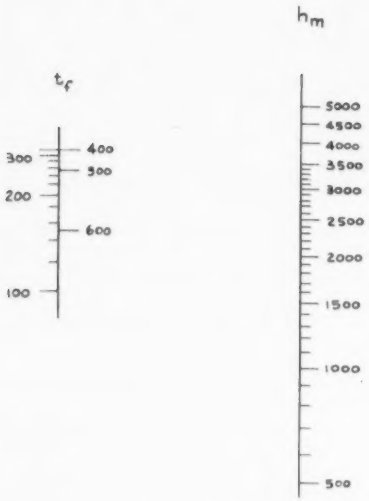
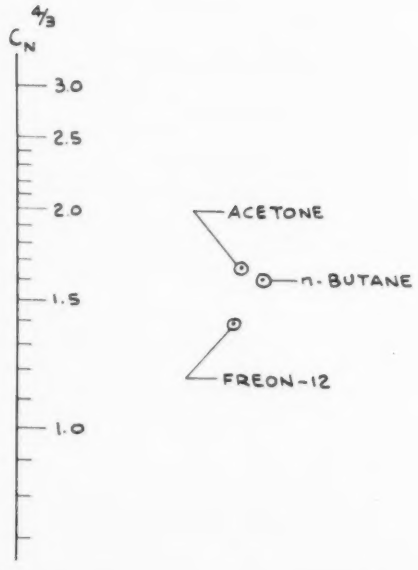
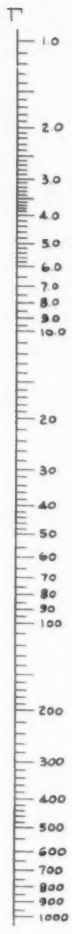
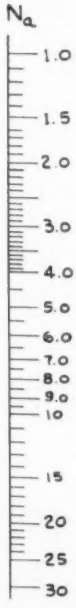


FIGURE 5 (above)—Condensing steam film coefficients for vertical surfaces restricted to $\Gamma/Z_t \leq 1090$. To obtain theoretical h_m for horizontal tubes, use above nomogram and multiply result by 0.8.

FIGURE 6 (below)—In order to use this nomogram for turbulence correction factor for horizontal multitube banks, first evaluate N_a by using Figure 3 to find n_s and then Equation (35) to solve for N_a.







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Does Your Sandblasting Cost too Much?

Using the wrong sand, hose, nozzle, air supply and sandblaster will cost you about ten times more for the job than it should cost

Paul E. Weaver
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SANDBLASTING can be unnecessarily costly. Expensive and inefficient materials and equipment are presently being used in some plants. Since there is very little difference between the cost of good and poor equipment and materials, you can realize substantial savings by adopting these recommendations in your plant.

For efficient sandblasting, consideration must be given to the following factors:

- Sand—size of grain, type, freedom from dust.
- Hose—size and type from air source to blaster and from blaster to nozzle; length of hose.
- Sandblast nozzle—size and type.
- Air supply—cubic feet per minute, pressure, freedom from water and oil.
- Sandblaster—continuous, intermittent.

The author has checked a number of sandblast operations and has found that, almost without exception, some or all of the above factors had not been considered properly for the job. The efficiency on some jobs was as low as 10 percent of that possible when proper consideration is given to these items.

Cleaning Equipment. The cost per square foot for cleaning steel is considerably less when good cleaning equipment is used. The price, for example, of a 6-inch-long, high-efficiency, tungsten-carbide nozzle is $35. It can be used for 800 hours of blasting, which is only 4.4 cents per hour. Cheap clay nozzles cost only 15 cents each, but after 2 hours of blasting time, they are so badly worn that they waste a considerable amount of sand and, even when new, they will not clean as efficiently as the 6-inch nozzle. The cost then is 7.5 cents per hour for the cheap nozzle. It is obvious that even without considering the time required to change the clay nozzles and the less efficient work they do, clay nozzles cost almost twice as much as do the good nozzles per hour of operation.

What is true of the nozzles is also true, in varying degrees, of the other factors listed—sand, air, and so on. Realizing that these factors do decidedly affect the quality and cost of sandblasting, let's have a look at each factor separately.

Sand. In general, for fastest cleaning and for obtaining the correct

TABLE 1—Friction Loss in Air Hose
(Pressure loss, psi, in 50 feet of hose); (Isothermal flow)

CFM Free Air	INSIDE DIAMETER OF HOLE							
	¾ Inch Initial Pressure				1 Inch Initial Pressure			
	60	80	100	125	60	80	100	125
60	2 67	2.08	1.70	1.40	0.78	0.61	0.50	0.41
70	3.64	2.84	2.31	1.88	1.05	0.82	0.67	0.55
80	4.78	3.68	3.01	2.45	1.34	1.06	0.86	0.71
90	6.00	4.65	3.84	3.10	1.73	1.34	1.11	0.89
100	7.56	5.77	4.68	3.80	2.07	1.61	1.33	1.09
125	12.6	9.3	7.44	5.88	3.23	2.51	2.05	1.67
150	18.9	13.8	10.9	8.64	4.69	3.45	2.95	2.39
175	.....	.....	.....	.....	6.48	4.86	4.08	3.27
200	.....	.....	.....	.....	8.70	6.54	5.27	4.27
	1¼ Inch				1½ Inch			
125	0.79	0.62	0.51	0.41	0.35	0.28	0.23	0.19
150	1.12	0.88	0.72	0.59	0.50	0.39	0.32	0.26
175	1.55	1.20	0.98	0.79	0.69	0.54	0.44	0.36
200	1.99	1.55	1.27	1.04	0.91	0.69	0.57	0.47
250	3.18	2.43	1.98	1.60	1.41	1.09	0.89	0.72
300	4.51	3.47	2.83	2.30	1.96	1.53	1.26	1.03
350	6.18	4.74	3.87	0.09	2.73	2.12	1.72	1.41
400	8.22	6.18	4.98	4.04	3.52	2.72	2.22	1.82
450	.....	.....	.....	.....	4.56	3.48	2.79	2.28
500	.....	.....	.....	.....	5.56	4.27	0.47	2.83
600	.....	.....	.....	.....	8.22	6.24	5.07	4.11

Notes—1. See Table 2 for cfm of free air required for various size nozzles at different pressures.
2. This table is based on straight hose with a smooth interior. A rough interior might increase the pressure loss by 50 percent or more. No allowance has been made for fittings. No short kinks or bends should be allowed in the hose.
3. For lengths longer or shorter than 50 feet, the pressure loss is approximately proportional to Table 1, provided that the distance does not exceed 400 feet or the mean flow velocity does not exceed 100 feet per second.

pattern depth on the steel surface for a coating thickness of 5 to 6 mils, use a graded flint or silica sand, 16-30 mesh; that is, zero percent retained on a 16-mesh screen, 100 percent retained on a 30-mesh screen. To be effective, the sand must be hard and have a low breakdown rate, preferably less than 10 percent. Samples should be taken at intervals to ascertain the breakdown rate. If it is greater than 10 per cent, then another source of sand should be found. Soft sand, or sand that breaks down too easily, does not clean as well as the harder sands and, in addition, leaves a very dusty surface, which must be cleaned.

The necessity for using the correct sand cannot be overemphasized. Remember that hardness, rate of breakdown and grain size are all very important, both for rapid work and for the preparation of a good surface pattern.

As an example, consider common river sand, which many people actually use. It contains approximately 80 percent sand and 20 percent dust and dirt. The breakdown of some river sand is approximately 40 percent. Then 40 percent of 80 percent equals 32 percent of the total mixture plus 20 percent of dust to begin with. It is seen then that after blasting, only 48 percent of the sand particles remain. Fifty-two percent is dust. It is the sand particles that do not break down that do the cleaning. A good silica sand will be 100 percent sand to start with and 92.5 percent after blasting. It is readily seen then that the "cheap" sand cleans (48 divided by 92.5) 52 percent as fast as the silica sand. This causes the cost per square foot (and that is the only logical basis to use) of labor, overhead, maintenance of equipment and sand to be approximately (92.5 divided by 48) 192.5 percent higher using the "cheaper" sand. Where the good sand would clean for 8 cents per square foot, the "cheap" sand would clean for (0.08 x 1.925) 15.4 cents per square foot.

Air and Sandblast Hose. Three sizes of nozzles are commonly used in general maintenance sandblasting; namely, ¼-inch, 5/16-inch, and ⅜-inch. From Table 1, it is readily seen that if the hose from the air source to the sandblaster is as much as 50 feet long, it should be at least 1-inch I.D. As given in Table 2, a ¼-inch nozzle uses 103 cubic feet of air per minute at 100 pounds per square inch; a 5/16-inch nozzle uses 161 cubic feet per minute and a ⅜-inch nozzles uses 232 cfm. Other sizes of nozzles are sometimes used. The air consumption of these nozzles is ⅛-inch—25 cfm, 3/16-inch—58 cfm and ½-inch—400 cfm.

The author has seen 100 feet or more of ¾-inch air hose leading from the air source to the sandblaster and the same length of hose used for the sandblast hose. Even if there is 100 psi constant pressure at the air source, there would be a 15.2-psi pressure drop at the sandblast nozzle if a ¼-inch nozzle were used and a 28.6-psi pressure drop if a 5/16-inch nozzle were used.

If a 1¼-inch hose were used above for the air hose and sandblast hose, the total pressure drop would only be 1.2 psi for a ¼-inch nozzle and 4 psi for a 5/16-inch nozzle. Then, using a 5/16-inch nozzle and a 1¼-inch I.D. hose, there would be 96 psi at the nozzle; whereas, using a 5/16-inch nozzle and a ¾-inch hose, there would be 71.4 psi at the nozzle. The rate of sandblast cleaning (square feet per hour) depends on the air pressure at the nozzle, not in the compressor receiver.

It can be seen that using the proper hose, as against an improper size which is very commonly used, the cleaning rate can be increased considerably, which materially reduces the cost per square foot for sandblasting steel.

In the foregoing discussion, it is assumed that it is not feasible to use a shorter hose on the particular set-up. It is always best to use the shortest hose possible, so that there will not be an excessive pressure drop.

For general use, the author recommends a 1-inch-I.D. air hose to the sandblaster if the hose isn't over 50 feet long. Over 50 feet, use a 1¼-inch-I.D. hose. The same thing applies to the sandblast hose. It is good practice to have a ¾-inch x 10-feet-long section of sandblast hose with the nozzle attached. This size hose is easier for the operator to maneuver and the 10-foot section does not cause much pressure drop.

TABLE 2—Air Required for Different Size Nozzles at Different Pressures
(In cfm of free air at standard atmospheric pressure of 14.7 psia and 70 F.)

Nominal Nozzle Size:	¼"		5/16"		⅜"		½"	
Nozzle Condition:	New	Old*	New	Old	New	Old	New	Old
Gage Pressure Before Nozzle								
60	67	134	105	210	151	302	268	538
70	76	152	119	238	171	342	304	608
80	85	170	133	266	191	382	340	680
90	94	188	146	292	211	422	376	752
100	103	206	161	322	232	464	412	624
110	112	224	175	350	252	504	448	896
120	121	242	189	378	272	544	484	968
125	125	250	195	390	281	563	500	1000

Note—This table is based on an orifice coefficient of flow of 99 percent.
* A nozzle should not be used after the orifice has worn to such an extent that the square of its diameter exceeds twice the square of the original diameter. Even at this point the air consumption is double that of a new nozzle.

SANDBLAST NOZZLES

Nozzle Size. There are three common sizes of sandblast nozzles used for general maintenance painting—1/4, 5/16 and 3/8 inch. In general, where sufficient air is available at the correct pressure, the larger size nozzles are preferable to the smaller ones because more area can be cleaned per hour with the same amount of labor cost. Using a ⅜-inch nozzle as the base size, Table 3 gives the relative cleaning rates of the three nozzles together with their air consumption.

It is easily seen then that, with a sufficient volume of air available, a ⅜-inch nozzle will clean (100 divided by 44.4) 2.25 times as fast as a ¼-inch nozzle.

Type of Nozzle. There are several different types of sandblast nozzles but those most commonly used are:

- Clay nozzles—cost approximately 15 cents each.

TABLE 3—Nozzle Cleaning Rates

Nozzle Size, In.	Rate of Cleaning	CFM of Air at 100 psi
¼	44.4% as fast as ⅜ in.	103
5/16	69.4% as fast as ⅜ in.	161
⅜	100%	232

- Cast-iron nozzles—cost approximately $2 each.
- Short hard nozzles—cost approximately $27 each.
- Long high efficiency tungsten-carbide nozzles—cost approximately $35 each.

Although the clay nozzles are used by a number of people, they are the most inefficient. Even from the start they do not blast as well as a better designed nozzle. They should not be used for more than 2 hours of continuous blasting because the orifice would be so badly worn that an excessive amount of sand would be wasted. The time required to change three or four nozzles per day is taken away from the blasting time, which decreases the rate per hour of cleaning.

The cast-iron nozzles are similar to the clay as to poor design but their life is somewhat longer. They are good for blowing sand away, but are not good for rapid, high-grade cleaning.

The short hard (tungsten-carbide) nozzles are far superior, both in design and long life, to the clay or cast-iron nozzles. These hard nozzles have a life of 800 hours of continuous blasting.

The most efficient nozzle is the long (6 inch), hard (tungsten-carbide), high-efficiency nozzle. This nozzle is designed for the sand particles to attain the maximum velocity as they leave the nozzle. The design also concentrates the sand particles in a compact pattern so maximum cleaning can be done in a minimum of time. These nozzles are good for 800 hours of actual blasting; or approximately 26 weeks at an average of 6 hours per day.

Nozzles should be discarded when the orifice is worn 50 percent greater in diameter than its original size. That is, a ¼-inch nozzle should be discarded when the orifice is worn to ⅜-inch diameter. This is necessary for efficiency because the design of the nozzle will have changed to such an extent that a large degree of efficiency is lost. The smallest part of the nozzle, the throat, is the first part to wear. It does not wear evenly; therefore, it is good business to discard a nozzle when it has worn 50 percent larger in diameter than when new.

A very good nozzle, which is also of the hard, high-efficiency type mentioned, is the venturi-style nozzle. This type nozzle not only develops a high velocity of air and abrasives leaving the nozzle, it also distributes the abrasive uniformly over an entire pattern, which permits an increase in production of from approximately 20 to 40 percent in some cases, at no extra cost for labor and material.

TABLE 4—Compressor Capacity

Nozzle Size, In.	CFM of Free Air	Receiver Pressure, psi
¼	150	100
5/16	240	100
⅜	393	100

Nozzle Holders. Holders should be used that fit outside the sandblast hose. Using this type holder, the sand does not come into contact with a nipple or ferrule, as in the case with the conventional holders. The sand contacts only the hardened nozzle. The nozzle, therefore, does not have to be removed until it is worn out.

With the conventional holder, which has a nipple inside the hose, there is an unnecessary restriction in the hose which causes a turbulence at that point. These nipples also cut out often because of sand flowing through them. This causes a delay in blasting, which is not experienced with the exterior-type holder.

Air Supply, Pressure, and Volume. The impact of the sand particles against the surface of the steel is what actually does the cleaning. The magnitude or force of this impact is a function of the air pressure; that is, the higher the pressure, the greater the force of the impact and, therefore, the faster the rust and scale is removed from the steel.

Usually 100 psi is considered the ideal working pressure. Pressures lower than 100 psi clean at a slower rate and a point is reached at around 60 psi where it is good practice not to sandblast since a considerably greater amount of sand and labor will be required to clean a square foot of steel.

Often 70 and 80 psi are used for sandblasting. This reduces the blasting efficiency by 20 to 30 percent or more.

Men in the field often do not realize the relation between static air pressure, volume of air available, and volume flow of air. They assume that if the gage reading is 100 psi before starting the sandblaster, you have or should have, 100 psi while blasting. This, however, is not necessarily the case. Primarily the volume of air at the desired pressure must be available and the correct size pipe and hose must be used from the air source to the sandblaster to assure the correct pressure-volume flow of air to the blaster. Allowing for normal nozzle wear, the available compressor capacity for each nozzle should be from 25 to 50 percent above the rated amount of air required for that size nozzle. In other words, under ideal conditions, which allow for nozzle wear, there should be at least the compressor capacity given in Table 4 for the nozzles listed.

With sufficient compressor capacity regarding pressure and volume and correct size pipe and hose, 97 to 98 psi air pressure can be maintained at the blast nozzle. Any good mechanical engineer's handbook, or machinery's handbook, will give data for correct size pipe for a given pressure-volume air flow. Flow of air in the hose is given in Table 1.

Continuous vs. Intermittent blasting. There are two general types of sandblasters—continuous and intermittent. As the names imply, one maintains a continuous flow of sand as long as the operator is sandblasting. With the other, the work is intermittent. Each time the hopper of 500 or 600 pounds of sand is emptied, there is a delay of from 5 to 10 minutes for filling the hopper again. It usually requires 30 to 40 minutes to use up 500 to 600 pounds; therefore, it is readily seen that only about 80 percent of the sandblast time is productive time. The balance of the time is used for the helper to fill the hopper while the operator is idle. These figures are based on actual time-and-motion studies and are not guesswork.

The continuous blaster, on the other hand, has a double-hopper arrangement so that the helper can keep the machine filled with sand and there is no interruption of the sandblasting. Actually, operators who have been polled on this matter prefer the continuous-type blaster. They still have the same amount of personal and fatigue time (30 to 40 minutes per 8-hour day) but during the operating time, they are produc-

ing 25 percent more work.

The continuous-type sandblaster costs approximately 40 to 50 percent more than the intermittent type; however, it does not take long to pay for this difference in cost because of increased efficiency.

Example. Usually, where vinyls are being applied, the operator sandblasts 6 hours out of the 8 hours and paints for 2 hours since no sandblasted surface should be left overnight without being painted. Of this, 6 hours—30 minutes are used for personal and fatigue time. That leaves 5½ hours for actual sandblasting. With the intermittent machine, which is only 80 percent efficient, we get only (5.5 x 0.8) 4.4 hours of effective blasting time. Whereas, with the continuous blaster, we get actually 5.5 hours of effective blasting time. With the intermittent blaster, the operator and helper are being paid for 1.1 hours each or a total of 2.2 man-hours per day while no production is being had. At $2.50 per hour, this would be $5.50 daily that the intermittent sandblaster is penalizing the company by not having a continuous sandblaster. This is direct labor cost only. The actual total cost is far more than this.

Sandblasting Costs. It seems ridiculous that the expensive and inefficient materials and equipment mentioned are presently in use, but the fact remains that this is the case.

Let's use the extremes in both cases—all of the most efficient materials and equipment on the one hand and all the least efficient on the other.

For the most efficient setup, we have:

1. Graded flint or silica sand; 16-30 grit.
2. Air hose of 1¼-inch I.D. to the sandblaster and 1¼-inch I.D. sandblast hose—50 feet of each.
3. Three-eighths inch sandblast nozzle—long, hard, high-efficiency type.
4. Exterior-type nozzle holder.
5. A minimum of 232 cfm of free air at 100 psi at source where sandblaster hose is connected.
6. Continuous-type sandblaster.

For the least efficient setup, we have:

1. Soft, ungraded river sand. Cleans approximately 52 percent as fast as 16-30 graded silica or flint.
2. One hundred feet of ¾-inch I.D. air hose, 50 feet of ¾-inch I.D. sandblast hose.
3. One-fourth-inch clay nozzle.
4. Interior-type nozzle holder.
5. Eighty cfm of free air at 100 psi at the compressor receiver.
6. Intermittent-type sandblaster.

Using the rate of sandblasting under the ideal setup as 100 percent, we can now see what we will have in comparison with the inefficient setup just described.

1. It was pointed out previously that some river sand cleans 52 percent as fast as 16-30 graded silica sand.

2. From Table 1, we see that 100 feet of 1¼-inch hose with air supply at 100 psi has a 3.4-psi pressure drop. Whereas, 150 feet of ¾-inch hose with an initial pressure of 100 psi has a pressure drop of 25.6 psi, or a pressure at the blast nozzle of 74.4 psi as against 96.6 psi for the ideal setup. This shows the hose setup for the inefficient job to be 77 percent as effective as the ideal setup.

About the Author

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3. As previously stated, the ¼-inch clay nozzles are less than 44.4 percent as efficient as the high-efficiency tungsten-carbide nozzles.

4. The interior-mounted nozzle holders are possibly less than 90 percent as efficient as the exterior-type holder.

5. Since a ¼-inch nozzle requires 103 cfm of free air at 100 psi for optimum cleaning speed, the 80 cfm supplied will cause the pressure, and therefore the cleaning rate, to decrease to approximately 80 percent of the rate possible with the correct amount of air. This factor has already been considered in the hose setup; however, since the volume of air is limited, the 80 percent factor is used to allow for the rapid wear of the clay nozzle and the resultant pressure drop.

6. The intermittent-type sandblaster is approximately 80 percent as efficient as the continuous-type blaster.

Now compare the over-all efficiency of the two setups.

Equate the ideal setup to 100 percent. Then, the inefficient, though commonly used setup, would equal: 100 (0.52) (0.77) (0.444) (0.90) (0.80) (0.80) = 10.2 percent.

This shows that the ideal setup is about ten times as efficient as the inefficient setup. In other words, steel that is properly cleaned under the ideal setup for 10 cents per square foot would cost $1.02 per square foot under the inefficient setup.

The author has carried out this example to impress upon the readers the fact that sandblasting, when not properly done with the correct material, equipment and personnel, can be very expensive. It need not be so.

The relative costs of the following items for sandblasting are:

Relative Sandblasting Costs	Percent
1 Labor and overhead	40
2 Compressed air	23
3 Sand	37
4 Equipment and miscellaneous	5

These are average ratios and will vary depending on a number of variables.

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REFERENCE

"Industrial Maintenance Painting," by P. E. Weaver; published by the author, 4025 Brady Street, Baton Rouge, La., second edition; 1958, Chapter 1.

Digital computer used to . . .

Figure Distillation This New Way

Part 1—New Convergence Method Will Handle Many Cases
Part 2—Product Purity Can Set Conditions for Column

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MULTICOMPONENT DISTILLATION calculations on a digital computer require all judgments and decisions to be stated beforehand. Furthermore, most computer methods use a series of successive approximations, and some means is needed to make successive results converge quickly to the answer.

This set of articles proposes a simple convergence method which causes a rapid approach to the desired solution. More than 50 different examples have been solved, including a wide variety of feeds and number of plates. The solutions for several have been obtained independently from a medium-scale and a large-scale digital computer. The method is readily applied and appears to be adequate in view of the success with which it has been used.

METHOD OF CONVERGENCE

The computer technique described here is based on a method proposed by Thiele and Geddes[18] and modified by others.[3, 4, 8, 11, 12] To solve the multicomponent distillation problems discussed in this first of two articles, the following column specifications are needed:

- Number of plates in each section
- Quantity, composition and thermal condition of the feed
- Column pressure
- Type of overhead condenser
- Reflux ratio or V_1 or L_o
- Quantity of distillate

To start the successive approximations, temperature and L/V profiles of the column are assumed. The convergence method is concerned then with the way in which the profiles are adjusted to make the specified quantity of distillate, D, at the specified reflux ratio, L_o/D.

The value of b_i/d_i obtained by a trial calculation through the column is denoted by $(b_i/d_i)_{ca}$, and the corrected value by the subscript "co," $(b_i/d_i)_{co}$. In these expressions, b_i is the molal withdrawal rate of component i in the bottom product and d_i is the molal withdrawal rate of component i in the distillate.

The corrected values, $(b_i/d_i)_{co}$, are defined as those which are in agreement with the specification D and satisfy both component and overall material balance. When these corrected values are used in a subsequent trial calculation they give a calculated value of D closer to the specified one than that obtained in the previous trial.

Thus, the problem was to develop an empirical expression relating the calculated values of the b_i/d_i's to the corrected values. The use of a multiplier, Θ, independent of any particular component, and defined by

$$\left(\frac{b_i}{d_i}\right)_{co} = \Theta\left(\frac{b_i}{d_i}\right)_{ca} \qquad (1)$$

was found to be adequate. In a subsequent section, theoretical significance is attached to the quantity Θ. The appropriate value of Θ to be used in any given trial must satisfy the equations developed in the following manner:

A material balance for component i requires

$$FX_{Fi} = (d_i)_{co} + (b_i)_{co}$$
$$= (d_i)_{co}\left[\ 1 + \left(\frac{b_i}{d_i}\right)_{co}\ \right] \qquad (2)$$

where F is the molal rate of flow of the entering feed and X_{Fi} is the total mole fraction of i in the feed. When the equivalent expression for $(b_i/d_i)_{co}$, Equation (1), is substituted in Equation (2), one obtains

$$(d_i)_{co} = \frac{FX_{Fi}}{1 + \Theta\,(b_i/d_i)_{ca}} \qquad (3)$$

Since the sum of the corrected values for the d_i's for all components is equal to the specified value of D, it is evident that

$$D = \sum_{i=1}^{c} \frac{FX_{Fi}}{1 + \Theta\,(b_i/d_i)_{ca}} \qquad (4)$$

The desired value of Θ is the positive root which gives $g(\Theta) = 0$, where

$$g(\Theta) = \sum_{i=1}^{c} \frac{FX_{Fi}}{1 + \Theta\,(b_i/d_i)_{ca}} - D \qquad (5)$$

A graph of the function $g(\Theta)$ is given in Figure 1. Equation (5) is readily solved for the desired value of

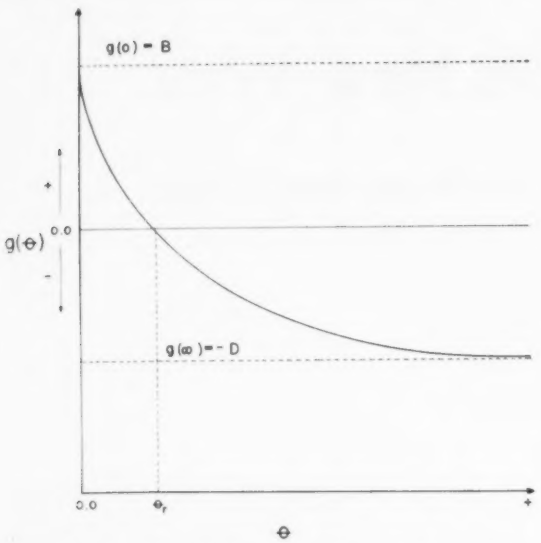

FIGURE 1—An empirical factor, Θ is used to compute the distribution of products by successive approximations.

Θ by any of several methods. One way uses Newton's method of repeated approximations.

In the application of Newton's method,[16] the first derivative of g (Θ) with respect to Θ is needed.

$$g'(\Theta) = -\sum_{i=1}^{c} \frac{FX_{Fi}\,(b_i/d_i)_{ca}}{[1+\Theta\,(b_i/d_i)_{ca}]^2} \qquad (6)$$

Newton's method consists of the repeated application of an expression obtained by making the approximation that

$$g(\Theta) = g(\Theta_a) + (\Theta - \Theta_a)\,g'(\Theta_a)$$

These are the first two terms of the Taylor's series expansion of g(Θ) about the particular value Θ_a, the value assumed for the positive root, Θ_r. When $\Theta = \Theta_r$, $g(\Theta_r) = 0$, and the above expression may be rearranged to

$$\Theta_r = \Theta_a - \frac{g(\Theta_a)}{g'(\Theta_a)} \qquad (7)$$

For $0 \leq \Theta \leq \Theta_r$, g(Θ) satisfies conditions which insure that repeated application of equation (7) will always yield Θ_r to the desired degree of accuracy. Thus $\Theta_a = 0$ should be assumed for the first application of Equations (5), (6) and (7).

After Θ_r, the desired value of Θ, has been calculated, the corrected values for the d_i's are obtained by substituting this value of Θ in Equation (3). The corrected b_i's may be calculated in a manner analogous to that indicated by Equation (9). The calculated values of the b_i's and d_i's are computed as follows:

$$(d_i)_{ca} = \frac{FX_{Fi}}{1+(b_i/d_i)_{ca}} \qquad (8)$$

$$(b_i)_{ca} = (b_i/d_i)_{ca}\,(d_i)_{ca} \qquad (9)$$

The mole fractions of each component in the vapor and liquid streams leaving plate j are calculated in the following manner.

$$y_{ji} = \sum_{i=1}^{c} \frac{(v_{ji}/d_i)_{ca}\,(d_i)_{co}}{(v_{ji}/d_i)_{ca}\,(d_i)_{co}} \qquad (10)$$

and

$$x_{ji} = \sum_{i=1}^{c} \frac{(l_{ji}/d_o)_{ca}\,(d_i)_{co}}{(l_{ji}/d_i)_{ca}\,(d_i)_{co}} \qquad (11)$$

Equivalent expressions for y_{ji} and x_{ji} in terms of b_i are obtained by replacing d_i in Equations (10) and (11) by b_i. The corrected temperature profile is obtained by making either dew points or bubble point calculations based on the compositions obtained as indicated by Equations (10) and (11). The entire procedure is repeated until the value of D calculated is approximately equal to the value of D specified. When the latter condition is realized, $\Theta_r \cong 1.0$. For those systems where L/V varies, the calculational procedure is altered to include enthalpy balances as discussed in a subsequent section.

SIGNIFICANCE OF Θ

Some theoretical significance may be attached to the quantity Θ through the consideration of idealized systems at total and at minimum reflux. Consider a system at total reflux, and let $(b_k/d_k)_1$ and $(b_k/d_k)_2$ denote two arbitrarily specified values for the base component k. When both of these distillations are carried out at the same number of equilibrium steps, N + 1, the corresponding values for b_i/d_i are given by Fenske's equation[5]:

$$\log (b_i/d_i)_1 = \log (b_k/d_k)_1 - (N+1)\log(\alpha_i/\alpha_k) \qquad (12)$$

$$\log (b_i/d_i)_2 = \log (b_k/d_k)_2 - (N+1)\log(\alpha_i/\alpha_k) \qquad (13)$$

In the following argument $(b_k/d_k)_1$ is taken to be greater than $(b_k/d_k)_2$. Substitution of the antilogarithms of the right hand sides of Equations (12) and (13) in Equation (8) and summing from i = 1 to i = c gives the expressions for the distillate rates D_1 and D_2. Also, one may think of D_1 and D_2 as the specified and calculated values of D; that is for a given set of calculated and specified values of D, there are corresponding systems at total reflux. Upon subtraction of Equation (13) from (12), one obtains a physical interpretation of Θ at total reflux, namely

$$(b_i/d_i)_1 = \Theta\,(b_i/d_i)_2$$

where,

$$\Theta = (b_k/d_k)_1/(b_k/d_k)_2$$

A graphical representation of Θ is shown in Figure 2.

If at minimum reflux one made the same sets of specifications for the two key components of the same system (where the keys are assumed to be adjacent with k being the least volatile key component), Figure 3 is obtained.

At the operating conditions, one can write equations of the same form as equations (12) and (13) with respect to the calculated and specified values of the (b_i/d_i)'s.

$$\log (b_i/d_i)_{co} = \log (b_k/d_k)_{co} - \log (\Omega_i)_{co} \qquad (14)$$

$$\log (b_i/d_i)_{ca} = \log (b_k/d_k)_{ca} - \log (\Omega_i)_{ca} \qquad (15)$$

where Ω_i is a function of the (b_i/d_i)'s of all of the

components, and the b_i/d_i's are, of course, functions of the remaining variables of the system.

If as a first approximation one takes $(\Omega_i)_{co}/(\Omega_i)_{ca}$ equal to unity, equations (14) and (15) reduce to Equation (1). A geometrical representation of the latter equation is shown in Figure 4, where the α's are evaluated at any arbitrarily selected temperature. It is seen that the proposed correction method is equivalent to shifting the curve of $(b_i/d_i)_{co}$ versus α_i/α_k up or down relative to the corresponding calculated curve in order to obtain the specified D.

As shown by the illustrative examples, the approximation of taking the ratio of the Ω's equal to unity tended to give calculated values of D which were alternately smaller and larger than the value specified for D. When a system exhibits this type of variation, it is possible in principle to obtain convergence with a minimum number of trials. Two arbitrary procedures were found which forced the calculated values of D to approach the specified value. These forcing procedures are included in the proposed method.

Another approach which gives rise to the quantity, Θ, is to find a set of corrected d_i's which satisfy simultaneously the specification (D or B) and Equations (2) and (11). When in Equation (11) $j = N + 1$, $l_{j1} = b_i$ and $x_{j1} = x_{B1}$. Since $Bx_{B1} = (b_i)_{co}$, multiplication of both sides of Equation (11) by B and rearrangement leads to Equation (1), where

$$\Theta = \frac{B}{\sum_{i=1}^{c} (b_i/d_i)_{ca} (d_i)_{co}} \qquad (16)$$

The expression for $(d_i)_{co}$ is obtained as shown previously by Equations (2) and (3). Equation (16) is equivalent to Equation (4) and could be used for the calculation of Θ.

The above approach is particularly useful in the treatment of side streams. When it is further specified that a side stream of rate, W, be withdrawn, one obtains in addition to the above expression

$$\Theta_1 = \frac{W}{\sum_{i=1}^{c} (w_i/d_i)_{ca} (d_i)_{co}} \qquad (17)$$

In the corresponding expression for $(d_i)_{co}$, another additive term, $\Theta_1(w_i/d_i)_{ca}$, appears in the denominator, where $\Theta_1(w_i/d_i)_{ca} = (w_i/d_i)_{co}$ and w_i is the flow rate of component i in stream W. Involved is the simultaneous solution of Equations (16) and (17) for the two desired values of Θ, which is to be treated in a subsequent paper.

FORCING PROCEDURES

The origin and use of forcing procedures are associated with the equilibrium and enthalpy functions. The first procedure was suggested by observing the temperature profiles for numerous examples in which the molal rates of flow were taken to be constant. Corresponding to the calculated values of D, which were alternately smaller and larger than the specified value for D, the calculated temperature profiles were alternately too high and too low. Reasoning that the best profile to be employed for the next trial calculation lay somewhere between these two led to the development of the averaging procedure. In this procedure, each calculated profile after the first one was averaged plate by plate with the profile used to make the particular trial calculation. In general, it was found that for systems in which the boiling range of the feeds was relatively narrow, convergence to the desired value of D was so rapid that the averaging of the profiles did not appreciably reduce the number of trials required; whereas, for systems in which the boiling range of the feeds was relatively wide, the number of trials required to obtain a D of the desired accurary was noticeably reduced by the averaging procedure. It should be pointed out, however, that all examples investigated at constant molal overflow converged without employing these forcing procedures.

The second forcing procedure was used in order to provide stability when the variation of the molal flow rates was taken into account. In general, it was found that the deviation of the calculated values of D from the specified value was amplified by the introduction of the enthalpy balances. This was due in part to the comparatively small differences between large numbers involved in the expressions for flow rates.

Since all problems in which the flow rates were assumed constant could be solved without applying a forcing procedure, it appeared plausible to limit the variation in the rates of flow between successive trials in the solution of problems in which these rates were varied. This was accomplished as follows:

- For the first two trial calculations, the same set of values for V and L were employed.
- The maximum value of any vapor rate calculated at the end of the second through the sixth trials was limited to 1.2 times the corresponding value used to make the particular trial calculation. The corresponding factor for the minimum rate was 1/1.2. At the end of the seventh and twelfth trials the limits were further reduced to 1.1 and 1/1.1 and to 1.025 and 1/1.025, respectively.
- The vapor rates calculated at the end of the third and each successive trial which lay within the above limits were averaged plate by plate with those employed to make the particular trial calculation.

These steps will be referred to as the second forcing procedure. This procedure was based on the solutions obtained for a large number of examples. For all of the examples considered, it gave the desired solution in near the minimum number of trials.

This procedure is based on the fact that the problems easily solved did not need a restriction on either the temperatures or the vapor rates; whereas, for the more difficult problems either the 10% or the 2.5% restriction as well as the averaging of the temperature profiles were needed in order to obtain the desired solution. Most of the problems encountered were solved within seven trials and in many instances where more than seven trials were required the changes in the vapor rates between successive trials were less than the limitations imposed. Whenever this occurred, all of the vapor rates were, of course, averaged.

In the application of the first forcing procedure (the averaging of the temperature profiles) to problems in which the rates of flow varied, the enthalpies of the

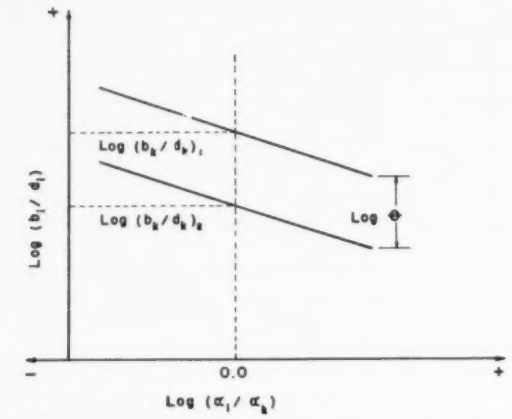

FIGURE 2—A graphical representation of Θ is obtained by considering two arbitrarily specified values for a base component, k, in a column under total reflux.

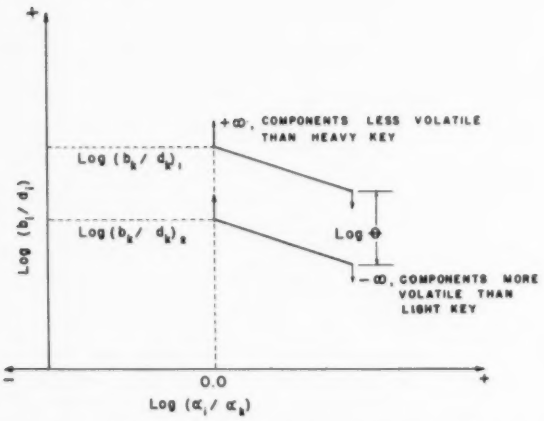

FIGURE 3—A column under minimum reflux gives a similar representation for Θ.

pure components were evaluated at the temperature profile obtained by averaging, while the compositions obtained at the end of the previous trial were used in the calculation of the enthalpies of the vapor and liquid streams. These compositions were, of course, those corresponding to the calculated bubble points. The equilibrium constants, K's, to be employed in the calculation of the absorption factors, A's, and stripping factors, S's, for the next trial were evaluated at the profile obtained by averaging.

The use of constant molal flow rates for the first two or more trials did not appear to be of major importance. Although an investigation of one trial versus two trial calculations at constant L/V was not made, it was found that in many instances the use of three trials at constant L/V instead of two necessitated one additional trial in order to obtain a D of a given accuracy.

OTHER RELATIONS NEEDED

To complete the computer program, a number of other relations must be stated beforehand. The important ones used for applying the convergence method follow.

Material Balance. The following equations are stated as molal quantities after Hummel.[8] Use is made of absorption and stripping factors as suggested by Donnell and Turbin.[3] The plates are numbered down from the top of each column; the partial condenser has the plate number zero, the top plate the number one, the feed plate the number f, the bottom plate the number N and the reboiler the plate number N + 1. The rectifying section includes only plates one through f — 1; the stripping section contains the remaining plates. In the rectifying section, each of the material balances is written around a given plate and the condenser; in the stripping section, each material balance includes a given plate and the reboiler. Statements of these balances follow.

Rectifying Section:

$$\frac{v_{1i}}{d_i} = A_{oi} + 1, \text{ (balance around condenser)} \qquad (18a)$$

$$\frac{v_{ji}}{d_i} = A_{j-1,i}\left(\frac{v_{j-1,i}}{d_i}\right) + 1, \quad 2 \leqq j \leqq f-1 \qquad (18b)$$

$$\frac{\bar{v}_{fi}}{d_i} = A_{f-1,i}\left(\frac{v_{f-1,i}}{d_i}\right) + 1 \qquad (18c)$$

Stripping Section:

$$\frac{l_{Ni}}{b_i} = S_{N+1,i} + 1, \text{ (balance around reboiler)} \qquad (19a)$$

$$\frac{l_{j-1,i}}{b_i} = S_{ji}\left(\frac{l_{ji}}{b_i}\right) + 1, \quad f+1 \leqq j \leqq N \qquad (19b)$$

$$\frac{\bar{l}_{f-1,i}}{b_i} = S_{fi}\left(\frac{l_{fi}}{b_i}\right) + 1 \qquad (19c)$$

where,

$A_{oi} = \dfrac{L_o}{K_{oi}\,D}$, for a partial condenser; for a total condenser, $A_{oi} = L_o/D$.

A_{ji} = absorption factor; $A_{ji} = L_j/K_{ji}\,V_j$.

$\bar{l}_{f-1,i}$ = molal rate at which component i, in the liquid state, flows onto the feed plate f; $\bar{l}_{f-1,i} = l_{f-1,i} + l_{Fi}$.

l_{Fi} = molal rate at which component i enters the column in the liquid part of the feed.

S_{ji} = stripping factor; $S_{ji} = K_{ji}\,V_j/L_j$ and $S_{N+1,i} = K_{N+1,i}\,V_{N+1}/B$.

$\bar{v}_{fi}$ = molal rate at which component i, in the vapor state, enters plate f — 1; $\bar{v}_{fi} = v_{fi} + v_{Fi}$.

v_{Fi} = molal rate at which component i enters the column in the vapor part of the feed.

The A_{ji}'s relate the v_{ji}'s and l_{ji}'s as follows: $l_{ji} = A_{ji}\,v_{ji}$, which was derived from the equilibrium relationship $x_{ji} = y_{ji}/K_{ji}$. Similarly, $v_{ji} = S_{ji}\,l_{ji}$ may be reduced to $y_{ji} = K_{ji}\,x_{ji}$. The quantities V_j and L_j appearing in the expressions for A_{ji} and S_{ji} are the total molal rates at which vapor and liquid, respectively, leave plate j. These rates are not always the same as those

at which the vapor and liquid streams enter plates j — 1 and j + 1, respectively. For instance when the feed is partially vaporized, the rate of flow of vapor to plate f — 1 is $\overline{V}_f = V_F + V_f$. With regard to the action on the feed plate, the usual assumption is made that upon entering the column, the feed flashes adiabatically and the resulting vapor contacts only and mixes perfectly with the vapor leaving the feed plate; whereas, the liquid part mixes perfectly with the liquid on the feed plate. The vapor and liquid parts of the feed are designated by V_F and L_F, respectively. A "bar" is used to denote the value of a flow rate or property of a stream upon arrival at a plate.

The absorption and stripping factors, A_{ji} and S_{ji}, are evaluated on the basis of an assumed temperature profile and a knowledge of the values of the molal flow rates at each plate. These rates are usually obtained by enthalpy balances. After the absorption factors have been evaluated, the (v_i/d_i)'s may be obtained by use of the recursion formula, Equation (18). Likewise, Equation (19) represents a recursion formula for the calculation of the (l_i/b_i)'s. After these recursion formulas have been applied, the next trial is initiated by the computation of b_i/d_i as discussed previously.

Enthalpy Balances. The enthalpies of one mole of vapor and of one mole of liquid leaving plate j are calculated by use of the following formulas:

$$H_j = \sum_{i=1}^{c} H_{ji}\, y_{ji} \qquad \text{(vapor)} \qquad (20)$$

$$h_j = \sum_{i=1}^{c} h_{ji}\, x_{ji} \qquad \text{(liquid)} \qquad (21)$$

where H_{ji} and h_{ji} are the enthalpies of the pure component i in the vapor and liquid streams, respectively, at the temperature of plate j.

In the rectifying section, the enthalpy balances are written around the condenser and any given plate and in the stripping section, the reboiler and any particular plate. After the rate of flow of the liquid or vapor stream has been calculated by an enthalpy balance, the second stream is calculated by an over-all material balance.

Rectifying Section:

$V_1 H_1 = L_o h_o + D H_D + Q_c$ (enthalpy balance around the condenser)

or,

$$L_o = \left[\frac{M_D - H_1}{H_1 - h_o}\right][D]$$

since $V_1 = L_o + D$

In general,

$$L_{j-1} = \left[\frac{M_D - H_j}{H_j - h_{j-1}}\right][D], \quad 1 \leqq j \leqq f-1 \qquad (22a)$$

$$L_{f-1} = \left[\frac{(M_D - H_f) - \dfrac{V_F}{D}(H_F - H_f)}{H_f - h_{f-1}}\right][D] \qquad (22b)$$

$$V_j = L_{j-1} + D, \qquad 1 \leqq j \leqq f-1 \qquad (22c)$$

$$\overline{V}_f = L_{f-1} + D$$

Stripping Section:

$$V_j = \left[\frac{h_{j-1} - M_B}{H_j - h_{j-1}}\right][B], \qquad f+1 \leqq j \leqq N+1 \qquad (23a)$$

$$V_f = \left[\frac{(h_{f-1} - M_B) - \dfrac{L_F}{B}(h_{f-1} - h_F)}{H_f - h_{f-1}}\right][B] \qquad (23b)$$

$$L_{j-1} = V_j + B, \qquad f+1 \leqq j \leqq N+1 \qquad (23c)$$

$$\overline{L}_{f-1} = V_f + B$$

where,

H_F, h_F = Enthalpies of one mole of the vapor and liquid parts of the feed, respectively.

$M_D = H_D + Q_c/D$; H_D represents the enthalpy per mole of distillate withdrawn, regardless of state, and Q_c is the condenser duty, the net heat removed by the condenser per unit time.

$M_B = h_B - Q_R/B$; Q_R is the reboiler duty, the net heat put into the system by the reboiler per unit time. Also, according to the numbering system $h_B = h_{N+1}$.

The condenser and reboiler duties are related by the over-all enthalpy balance

$$Q_R = DH_D + Bh_B + Q_c - FH \qquad (24)$$

The symbol H represents the total enthalpy per mole of feed entering the column.

$$H = \frac{V_F}{F} \sum_{i=1}^{c} H_{Fi}\, y_{Fi} + \frac{L_F}{F} \sum_{i=1}^{c} h_{Fi}\, x_{Fi} \qquad (25)$$

Different Thermal Conditions for Feeds. When the calculations are carried out in terms of mole fractions, equations for the calculation of x_{Di}/x_{Bi} for feeds of various thermal conditions have been stated by various authors, among whom were Thiele and Geddes[18] and Rea and Hanson.[12] Expressions for the molal ratio, b_i/d_i, are stated in Table 1. When these relations are used for calculations at constant flow rates, it should be pointed out that the appropriate values of L/V must be used in

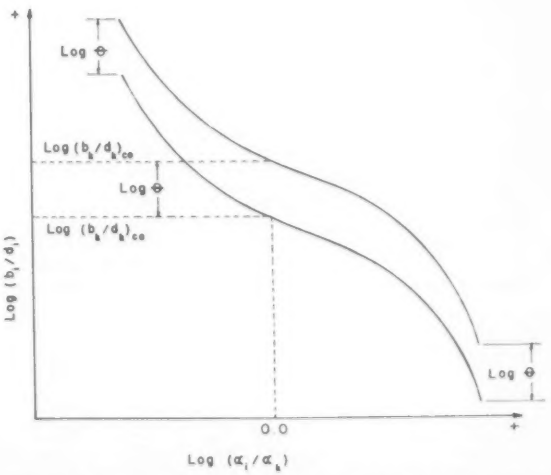

FIGURE 4—The proposed correction method is equivalent to shifting the curve up or down to satisfy the desired value of total distillate.

Equations (18) and (19) in the neighborhood of the feed plate.

Bubble and Dew Points. In the process of solving the numerous examples, Newton's method, direct iteration and interpolation were employed for the calculation of the bubble and dew points. In all instances a power of either the equilibrium constant or of the relative volatility, α, was correlated as a power function of temperature. The equations corresponding to the bubble point calculations follow.

1. Newton's Method:

$$T = T_a - \frac{f(T_a)}{f'(Ta)}$$

$$f(T) = \left(\sum_{i=1}^{c} K_{ji}\, x_{ji} \right) - 1$$

TABLE 1—Equations for b_i/d_i

Thermal Condition of Feed	Relationships
Boiling Point and Subcooled Liquid	$v_{fi} = \bar{v}_{fi};\ l_{Fi} = FX_{Fi};\ v_{Fi} = 0$; $\frac{b_i}{d_i} = \frac{(\bar{v}_{fi}/d_i)}{(v_{fi}/b_i)}$
Dew Point and Superheated Vapor	$l_{f-1,i} = \bar{l}_{f-1,i};\ l_{Fi} = 0;\ v_{Fi} = FX_{Fi}$; $\frac{b_i}{d_i} = \frac{(l_{f-1,i}/d_i)}{(\bar{l}_{f-1,\,i}/b_i)}$
Partially Vaporized	$\bar{v}_{fi} = v_{fi} + v_{Fi}\bar{l}_{f-1,i} = l_{f-1,i} + l_F$
General expression for b_i/d_i for feed of any thermal condition	$\frac{b_i}{d_i} = \frac{\left(\frac{l_{f-1,i}}{d_i}\right) + \left(\frac{l_{Fi}}{FX_{Fi}}\right)}{\left(\frac{v_{fi}}{b_i}\right) + \left(\frac{v_{Fi}}{FX_{Fi}}\right)}$

TABLE 2—Feed Compositions

Comp.	FX_F FOR EXAMPLES SHOWN					
	1	2,3,4,5,6	7	8	9	10
H_2	0.0	0.0	5.0	0.0	0.0	0.0
CH_4	0.0	2.0	2.0	2.0	4.0	8.0
C_2H_6	0.0	10.0	10.0	10.0	10.0	10.0
C_3H_6	0.0	6.0	6.0	6.0	6.0	6.0
C_3H_8	5.0	12.5	12.5	12.5	12.5	12.5
i-C_4	15.0	3.5	3.5	3.5	3.5	3.5
n-C_4	25.0	15.0	15.0	15.0	15.0	15.0
i-C_5	20.0	0.0	0.0	0.0	0.0	0.0
n-C_5	35.0	15.2	15.2	15.2	15.2	15.2
C_6	0.0	11.3	11.3	11.3	11.3	11.3
C_7	0.0	9.0	9.0	9.0	9.0	9.0
C_8	0.0	8.5	8.5	8.5	8.5	8.5
360	0.0	7.0	7.0	7.0	14.0	28.0
450	0.0	0.0	0.0	10.0	0.0	0.0
Total	100.0	100.0	105.0	110.0	109.0	127.0

$$f'(T) = \sum_{i=1}^{c} x_{ji} \frac{d(K_{ji})}{dT} \qquad (26)$$

These equations are applied in a manner analogous to that stated previously for Equations (5), (6) and (7).

2. Direct Iteration (Use of α, relative volatility)

$$K_{j\,k} = \frac{1}{\sum_{i=1}^{c} \alpha_{ji}\, x_{ji}} \qquad (27)$$

In this conventional method, the temperature corresponding to K_k for the base component is taken as the assumed value for the next trial.

3. Interpolation (Use of K/T)

When the temperature is selected as the equilibrium constant of the base component k, one obtains $\alpha_i = K_i/T$. When this selection is made, Equation (27) gives the temperature directly. However, in most cases direct iteration did not converge and a method of interpolation (regular falsi) described by Sokolnikoff[16] was employed. This method was employed for the determination for the bubble point temperature, T, which gives $F(T) = 0$, where,

$$F(T) = T\left[\sum_{i=1}^{c} (K_{ji}/T)\, x_{ji} \right] - 1 \qquad (28)$$

GENERAL CALCULATIONAL PROCEDURE

The following procedure was used in solving all examples.

(1) Assume a temperature profile for the column.

(2) Assume values for those flow rates which are not specified but are necessary to make the first trial calculation.

(3) Carry out the first two trial calculations on the basis of the molal flow rates assumed in (2).

(4) After the corrected b_i/d_i's have been evaluated, calculate the compositions and corresponding temperature profile. At the end of the second and all subsequent trials, treat the temperature profiles as described in the section on forcing procedures.

(5) After the first two trials, calculate the molal rates of flow by enthalpy balances based on the compositions and temperatures obtained in (4) and treat these flows as described in a previous section on forcing procedures.

(6) On the basis of the temperature profile obtained

TABLE 3—Statement of Examples

EXAMPLE	Initial Temp. Profile	Feed Condition	Distillate Rate	Reflux Ratio L₀/D	No. of Stages	No. of Feed Plate*	Type of Condenser	Column Pressure (psia.)
1	Linear (130°-250°F)	Boiling Point Liquid	48.9	2.58	10	5	Total	120
2	Linear (50°-450°F)	Boiling Point Liquid	31.6	2.0	13	4	Partial	264.7
3	Constant 150°F	Boiling Point Liquid	31.6	2.0	13	4	Partial	264.7
4	Constant 300°F	Boiling Point Liquid	31.6	2.0	13	4	Partial	264.7
5	Linear (50°-450°F)	50 Percent Vapor	31.6	2.0	13	4	Partial	264.7
6	Linear (50°-450°F)	Boiling Point Liquid	31.6	2.0	51	13	Partial	264.7
7	Linear (50°-450°F)	Boiling Point Liquid	36.6	1.72	13	4	Partial	264.7
8	Linear (50°-450°F)	Boiling Point Liquid	31.6	2.3	13	4	Partial	264.7
9	Linear (50°-450°F)	Boiling Point Liquid	33.6	2.08	13	4	Partial	264.7
10	Linear (50°-450°F)	Boiling Point Liquid	35.6	2.14	13	4	Partial	264.7

* The plates were numbered down from the top of the column with the partial condenser being designated zero and the top plate being numbered one.

in (4) and the L and V values from (2) or (5) evaluate the A's and S's needed for the next trial calculation.

In the programs used to obtain the results shown in the examples which follow, the calculations were started at each end of the column and carried to the feed plate. Actually, the calculations may be initiated at either end and taken through the entire column.

For example, suppose the calculations are initiated at the bottom of the column. The ratio, v_{f1}/b_1, is calculated by application of the stripping section equations as described previously. Before further stepwise calculations may be performed, it is necessary to evaluate $(b_1/d_1)_{ca}$ and $(b_1)_{ca}$ because the material balance enclosing the bottom of the column and the feed plate or any plate above it contains the unknown b_1. An outline of the derivation of the desired expression for b_1/d_1 follows.

A material balance around the bottom of the column and the feed plate yields

$$\frac{l_{f-1,1}}{b_1} = \frac{v_{f1}}{b_1} + \left(1 - \frac{l_{F1}}{b_1}\right)$$

and a material balance enclosing plate f — 1 gives

$$\frac{l_{f-2,1}}{b_1} = (S_{f-1,1})\left(\frac{l_{f-1,1}}{b_1}\right) + \left(1 - \frac{FX_{F1}}{b_1}\right)$$

When $l_{f-1,1}/b_1$ is eliminated from these two equations, one obtains

$$\frac{l_{f-2,1}}{b_1} = (S_{f-1,1})\left(\frac{v_{f1}}{b_1}\right) + (S_{f-1,1})\left(1 - \frac{l_{F1}}{b_1}\right) + \left(1 - \frac{FX_{F1}}{b_1}\right)$$

Use of the over-all material balance, $FX_{F1} = b_1 + d_1$, permits the above expression to be stated as follows:

$$\frac{l_{f-2,1}}{b_1} = S_{f-1,1}\left(\frac{v_{f1}}{b_1}\right) + S_{f-1,1}\left[\frac{v_{F1}}{FX_{F1}} - \frac{l_{F1}}{FX_{F1}}\left(\frac{b_1}{d_1}\right)\right] - \frac{b_1}{d_1}$$

A continuation of this substitutional process throughout the remainder of the rectifying section leads to the desired expression.

$$\left(\frac{b_1}{d_1}\right)_{ca} = \frac{1 + \Phi_1 + \phi_1\left(\frac{l_{F1}}{FX_{F1}}\right)}{\left(\frac{v_{f1}}{b_1} + \frac{v_{F1}}{FX_{F1}}\right)\phi_1} \qquad (29)$$

where,

$$\phi_1 = S_{o1}\,S_{11} \cdots\cdots S_{f-2,1}\,S_{f-1,1}$$

$$\Phi_1 = S_{o1}\,S_{11} \cdots\cdots S_{f-3,1}\,S_{f-2,1} + S_{o1}\,S_{11} \cdots\cdots S_{f-4,1}\,S_{f-3,1} + \cdots\cdots + S_{o1}\,S_{11} + S_{o1}$$

TABLE 4—Equilibrium and Enthalpy Data for Example 1

Comp.	a_1	a_2	a_3	c_1	c_2	c_3	e_1	e_2	e_3
C_3H_8	11.06095	—5.20067	0.92489	0.00000	2521.92	175.417	7488.65	1750.51	79.273
i-C_4	4.69290	—1.82431	0.31755	0.00000	3345.00	150.000	9592.01	1843.56	221.433
n-C_4	3.07033	—0.83565	0.12144	0.00000	2960.00	400.000	8002.89	4382.70	—401.587
i-C_5	1.00000	0.00000	0.00000	0.00000	3681.33	283.334	11645.77	2770.55	156.345
n-C_5	0.73827	0.05246	0.00189	0.00000	3845.00	250.000	12004.88	3168.66	67.456

$$K\ (\text{for i} - C_5) = 0.37088 - 0.55786\left(\frac{T}{100}\right) + 0.44841\left(\frac{T}{100}\right)^2 - 0.03704\left(\frac{T}{100}\right)^3,\ T \text{ in } °F$$

$$\alpha_i = a_{1i} + a_{2i}\left(\frac{T}{100}\right) + a_{3i}\left(\frac{T}{100}\right)^2,\ T \text{ in } °F$$

$$h_i = c_{1i} + c_{2i}\left(\frac{T}{100}\right) + c_{3i}\left(\frac{T}{100}\right)^2,\ T \text{ in } °F$$

$$H_i = e_{1i} + e_{2i}\left(\frac{T}{100}\right) + e_{3i}\left(\frac{T}{100}\right)^2,\ T \text{ in } °F$$

Equilibrium data taken from Reference (15)
Enthalpy data taken from Reference (10).

TABLE 5—Equilibrium and Enthalpy Data for Examples 2-10

Comp.	a_1	a_2	a_3	c_1	c_2	c_3	e_1	e_2	e_3
H_2	436.36196	—257.95576	38.22382	285.48	151.52	7.377	678.00	99.64	1.9395
CH_4	63.76528	— 29.51969	4.25794	1840.25	1345.33	— 11.110	4864.17	773.26	19.0294
C_2H_6	10.93719	— 3.88431	0.55580	3147.12	2222.47	10.935	8483.48	1280.67	65.9954
C_3H_6	4.03335	— 1.14742	0.17389	4213.82	2874.12	40.076	11254.87	1746.81	102.5564
C_3H_8	3.64797	— 1.06605	0.16197	4425.16	2968.64	48.868	11806.71	1797.38	112.6239
i-C_4	1.46077	— 0.18097	0.02721	5320.76	3525.03	90.076	13726.02	2261.20	167.3186
n-C_4	1.00000	0.00000	0.00000	5553.24	3641.27	90.076	14851.06	2312.00	155.9965
C_5	0.17185	0.22019	— 0.02826	6663.21	4161.81	160.848	18757.52	2903.45	233.0578
C_6	0.00541	0.14775	— 0.01056	7661.12	4658.30	231.661	20445.36	3207.59	287.9913
C_7	— 0.02141	0.07538	0.00061	8676.69	5066.88	310.574	23038.41	3713.28	328.7941
C_8	— 0.01184	0.02524	0.00593	9845.04	5353.77	403.497	25539.97	4119.20	405.9716
360	— 0.00145	— 0.00053	0.00430	11509.74	6023.85	599.071	30246.89	5121.06	524.2676
450	0.01431	— 0.02071	0.00637	13897.03	6634.93	880.067	35971.05	6455.20	669.7070

$$K\ (\text{for n} - C_4) = -0.04195 + 0.34087\left(\frac{T}{100}\right) - 0.01815\left(\frac{T}{100}\right)^2 + 0.02872\left(\frac{T}{100}\right)^3,\ T \text{ in } °F$$

$$\alpha_i = a_{1i} + a_{2i}\left(\frac{T}{100}\right) + a_{3i}\left(\frac{T}{100}\right)^2,\ T \text{ in } °F$$

$$h_i = c_{1i} + c_{2i}\left(\frac{T}{100}\right) + c_{3i}\left(\frac{T}{100}\right)^2,\ T \text{ in } °F$$

$$H_i = e_{1i} + e_{2i}\left(\frac{T}{100}\right) + e_{3i}\left(\frac{T}{100}\right)^2,\ T \text{ in } °F$$

Equilibrium data taken from Reference (13).
Enthalpy data taken from Reference (10).

Figure Distillation This New Way . . .

For a partial condenser, $S_{01} = (K_{01}D)/L_0$ and for a total condenser, $S_{01} = D/L_0$. Equation (29) is valid for a feed of any thermal condition. After $(b_i/d_i)_{ca}$ has been evaluated by use of Equation (29), $(b_i)_{ca}$ is readily obtained by Equations (8) and (9). Then the (l_i/b_i)'s for each plate are obtained by use of material balance equations. The calculation of the $(d_i)_{co}$'s and $(b_i)_{co}$'s, the corrected temperature profile and the molal rates of overflow is effected as discussed previously.

It should also be pointed out that less computer storage space is required in the application of the Thiele and Geddes method when only the b_i/d_i's are stored in the first calculation through the column. On the basis of these values, the corrected b's and d's are calculated as described previously. In order to calculate the compositions, temperatures and vapor rates, a second calculation through the column is required. In this calculation, the molal ratios are evaluated by use of the same equations employed in the first trial calculation. The compositions associated with each plate are calculated as indicated by Equations (10) and (11). The calculation of the temperature profile and the vapor and liquid rates is carried out in the same manner as described previously. Storage of only V/L and the averaged temperature of each plate is required in order to carry out the next trial.

Since this paper is concerned primarily with the Θ-method, a comment on how it might be used with the calculational procedure proposed by Lewis and Matheson[9] follows. For the purpose of illustration, the case where the feed enters the column as a liquid at its bubble point is considered. After the moles of each com-

TABLE 6—Temperature Profiles (Θ-method without forcing procedures) and Distillate Rates for Example 1

	Initial	TRIAL NUMBER 1	2	3	4	5	6
Temperature on Plate No., °F							
0 (Distillate)	130.00	146.34	147.55	147.60	147.63	147.63	147.63
1	130.00	164.44	165.57	165.64	165.71	165.71	165.71
2	143.33	180.08	179.30	179.34	179.41	179.40	179.40
3	156.67	195.19	189.80	189.88	189.91	189.89	189.90
4 (Feed)	170.00	208.10	196.82	197.50	197.38	197 37	197.38
5	183.33	217.46	200.51	202.78	202.22	202.31	202.30
6	196.67	223.20	211.05	211.89	211.51	211.56	211.56
7	210.00	228.14	219.41	219.56	219.29	219.32	219.32
8	223.33	231.93	225.86	225.75	225.59	225.60	225.60
9	236.67	234.65	230.69	230.54	230.43	230.45	230.45
10 (Bottoms)	250.00	236.56	234.25	234.14	234.08	234.09	234.09
D (Calculated by Θ — method)	.....	41.82	52.40	48.65	49.01	48.93	48.94
D (Calculated by direct iteration)	.....	41.82	43.68	44.86	46.04	47.04	47.67

NOTE: All distillate rates (Θ-method) after the first one were calculated on the basis of the temperature profile calculated in the previous trial. Thirteen additional trials were required to obtain a D of 48.94 by direct iteration.

TABLE 7—Temperature Profiles (Obtained by Use of Forcing Procedures of the Θ-method) and Distillate Rates for Example 2

	TRIAL NUMBER 1	2	3	4	5	6	7	8	12
Temperature on Plate No., °F									
0 (Distillate)	90.34	93.01	92.74	92.32	92.17	92.14	92.13	92.13	92.13
1	119.45	119.50	118.49	117.36	116.60	116.13	115.84	115.66	115.41
2	148.15	145.19	141.39	138.15	136.20	135.08	134.44	134.08	133.65
3	178.50	172.84	165.81	160.18	157.28	155.87	155.19	154.86	154.53
4 (Feed)	223.05	217.87	206.13	197.25	194.45	193.91	193.88	193.90	193.86
5	226.59	229.91	224.99	219.32	217.19	216.63	216.54	216.56	216.56
6	230.95	238.23	237.21	233.86	232.37	231.88	231.77	231.76	231.77
7	236.32	245.31	246.56	244.87	243.91	243.51	243.38	243.35	243.35
8	243.57	252.50	254.71	254.03	253.40	253.07	252.92	252.87	252.85
9	254.26	261.36	263.29	262.99	262.51	262.20	262.04	261.97	261.94
10	270.47	274.04	274.65	274.24	273.79	273.50	273.35	273.29	273.26
11	294.98	294.25	293.25	292.73	292.44	292.29	292.22	292.19	292.19
12 (Bottoms)	334.09	333.09	332.95	333.04	333.10	333.13	333.15	333.16	333.16
D (Calculated by Θ — method)	30.61	31.71	32.16	32.10	31.79	31.67	31.62	31.611	31.601
D (Calculated by direct iteration)	30.61	29.41	29.99	30.42	30.53	30.61	30.75	30.79	31.08

NOTE: By direct iteration a D = 31.47 was obtained at the end of 23 trials with distillate and bottoms temperatures of 90.84° F and 332.7° F, respectively.

TABLE 8—Vapor Rates Using Forcing Procedures of the Θ-method

PLATE NUMBER	TRIAL NUMBER FOR EXAMPLE 1 2*	3	4	8	TRIAL NUMBER FOR EXAMPLE 2 2†	3	4	5	7
1	175.0	175.0	175.0	175.0	94.8	94.8	94.8	94.8	94.8
2	172.8	171.5	170.9	170.6	95.3	94.0	93.5	93.3	93.0
3	170.7	168.6	167.7	167.4	92.9	91.0	90.5	90.1	89.4
4	169.8	167.3	166.2	165.6	86.9	83.8	83.2	82.2	80.5
5	170.1	167.4	166.1	164.8	113.8	117.9	112.0	110.1	110.2
6	172.8	170.1	168.2	165.7	113.8	128.4	125.9	124.4	124.0
7	172.8	170.4	168.7	166.6	113.8	133.3	133.6	132.7	132.2
8	172.9	170.8	169.4	167.5	113.8	135.3	138.0	138.0	137.7
9	173.0	171.2	169.9	168.4	113.8	135.2	139.7	140.6	140.7
10	173.1	171.4	170.3	169.1	113.8	133.4	138.9	140.4	140.8
11	.....	.....	.....	.....	113.8	129.6	134.7	136.2	136.4
12	.....	.....	.....	.....	113.8	120.4	122.4	122.9	122.7

* Vapor rate assumed constant at 175.0 for the first two trials.
† Vapor rate assumed constant at 94.8 for the first two trials.

ponent in the vapor leaving the feed plate have been calculated by the stepwise procedure by use of both the rectifying and stripping section equations, the ratios $\bar{v}_{fi}/d_i$ and v_{fi}/b_i may be evaluated, where $\bar{v}_{fi}$ and v_{fi} denote the moles of component i in the vapor as calculated by use of the rectifying and stripping section equations, respectively. The calculated value of b_i/d_i is defined by the following equation.

$$\frac{(\bar{v}_{fi}/d_i)}{(v_{fi}/b_i)} = \left(\frac{b_i}{d_i}\right)_{ca}$$

It will be observed that any inequality in the v's is absorbed in the ratio b_i/d_i. The corrected d's and b's to be employed in the next trial calculation are calculated as indicated by Equations (1) through (9). However, no problems have been solved using a combination of the Θ-method and the procedure of Lewis-Matheson. Thus, the convergence properties and the forcing procedures required for this combination are unknown, although several recent methods for other ways to carry out multicomponent distillation are listed in the reference.[1, 2, 14]

ILLUSTRATIVE EXAMPLES

Statements of the illustrative examples are given in Tables 2 and 3. Tables 4 and 5 contain the equilibrium and enthalpy data. The solutions of the first two of these are given in detail; whereas, for the remaining examples only the final results are shown.

This series of illustrative examples was selected in order to demonstrate the effect of the boiling range, composition and thermal condition of the feed, the number of plates and the temperature profile initially assumed on the number of trials required for convergence. Example 1 consists of components having a relatively narrow boiling range compared with those of Example 2. The latter is a slight modification of the gasoline-stabilization example solved by Robinson and Gilliland.[13]

In addition to the correction method described previously and referred to now as the "Θ-method," a second method, designated "direct iteration," was briefly investigated. The application of the method of direct iteration to problems with constant molal overflows has been demonstrated by Donnell and Turbin[3] and Rea and Hanson.[12] This method differs from the Θ-method in that the corrected temperature profile to be employed for the next trial is calculated on the basis of the calculated values of the d_i's and b_i's. Where required in the remainder of the calculational procedure, the specified values of D, B, and L_o/D are, of course, employed. When direct iteration was used to solve problems involving variable rates of flow, it was sometimes necessary to limit the change in these rates between successive trials. Such a limit was not necessary in the cases of Examples 1 and 2.

For all of the problems for which a comparison has been made, the method of direct iteration gave a smaller correction for each trial than was obtained with the Θ-method. This is reflected by the relative rates of convergence of the two methods for Examples 1 and 2. The values of D as calculated by each of the methods for each trial are shown in Tables 6 and 7. The temperature profile shown in Table 6 was obtained by the Θ-method without employing either of the forcing procedures. As shown in Table 6, the Θ-method gave values of D which were alternately smaller and larger than the specified value of D. On the other hand, the values obtained by direct iteration were smaller than the specified value and several more trials were required to obtain a D of the same accuracy as the one calculated by the Θ-method.

In order to demonstrate the relative effect of the boiling range on the number of trials required by the Θ-method, Example 2 was selected. The results obtained by the Θ-method are shown in Table 7. The effect of the second forcing procedure is illustrated by Example 2, Table 8. This table also shows that for systems such as Example 1, in which the enthalpy functions were relatively insensitive, the limits of the second forcing procedure were never applied because all of the calculated vapor rates were within the permissible range of values. Furthermore, it should be noted that although the application of the first forcing procedure tended to diminish the change in vapor rates between trials, the calculated change in some cases exceeded one or both of the limits being used by the second forcing procedure, as in Example 2, Table 8.

A comparison of Tables 6 and 9 shows that the use of the forcing procedures of the Θ-method in the solution of Example 1, increased the number of trials required to obtain D's of a given accuracy. For all problems of this type which have been solved, the use of the forcing procedures gave the desired solution in ten trials or less. Although some speed is sacrificed in the solution of the relatively easy problems, the use of the forcing procedures made it possible to solve all problems which have been attempted—such as Example 2.

As shown in Table 9, Example 5 proved the most difficult to solve. This was because the small vapor rates in the stripping section were rather sensitive to small changes in temperature and composition.

One other characteristic of the Θ-method which is of considerable practical value is that approximately correct temperatures for the distillate and bottoms are calculated after the first few trials; this indicates the product distribution is nearly correct. This characteristic is illustrated in Table 9. Direct iteration did not provide such a rapid approach to the final product distribution.

The computing time was about 0.3 seconds (floating point arithmetic) per component per plate per trial for one large-scale digital computer and 0.15 seconds for fixed point arithmetic. The corresponding time for a medium-scale digital computer was 6 to 10 seconds (floating point arithmetic). In the writing of these initial programs, speed was not the first consideration. Further improvement and wider application of the methods de-

TABLE 9—Final Results Obtained by Θ-method for Examples 1-10

Example Number	Trials Req'd for $\frac{\Delta D}{D} = \pm 0.01$	Temperature, °F		Trials Req'd for $\frac{\Delta D}{D} = \pm 0.001$	Temperature, °F	
		Distillate	Bottoms		Distillate	Bottoms
1	5	147.59	234.28	8	147.62	234.09
2	5	92.17	333.10	7	92.13	333.15
3	5	92.20	332.83	7	92.14	333.09
4	5	92.17	332.99	6	92.16	333.07
5	7	114.56	320.72	12	114.21	320.55
6	5	89.57	334.34	8	89.52	334.37
7	6	79.43	333.49	9	79.36	333.58
8	5	91.88	352.72	7	91.85	352.76
9	6	86.75	346.43	8	86.72	346.47
10	6	78.26	369.25	8	78.23	369.30

scribed herein are expected to result from the investigation now in progress.

Part 1 is essentially the same material as presented at the AIChE meeting in Salt Lake City, September, 1958. Part 2 will extend the Θ-method to include other types of product specifications.

SYMBOLS USED

a—Constant used to denote a sum of X_D's or x_B's.

A_{ji}—Absorption factor for plate j and component i.

b_i—Molal withdrawal rate of component i in the bottom product.

B—Molal withdrawal rate of bottoms.

c—Total number of components.

d_i—Molal withdrawal rate of component i in the distillate.

D—Molal withdrawal rate of distillate.

f—Number of the feed plate.

F—Molal rate of flow of the entering feed.

$f(T), f'(T)$—A bubble point function and its first derivative; see Equation (26).

$F(T)$—A bubble point function; defined by Equation (28).

$g(\Theta), g'(\Theta)$—Used to denote the function and its first derivative respectively; defined by Equations (5) and (6).

H_{ji}, h_{ji}—Enthalpy of one mole of a pure component i in the vapor and liquid states, respectively, at the temperature of plate j.

H_j, h_j—Enthalpy of one mole of the vapor and of one mole of the liquid leaving plate j, respectively.

k—Used to denote the base component; the component for which $\alpha = 1.0$.

K_{ji}—The Henry law constant ($y = Kx$) for component i at the temperature of plate j.

l_{ji}—Molal rate at which component i in the liquid state leaves plate j.

$\bar{l}_{f-1,i}$—Molal rate of flow of component i in the liquid state onto plate f.

l_{Fi}—Molal rate of flow of component i in the liquid part of a partially vaporized feed.

L_j—Total molal rate of flow of liquid from plate j.

$\bar{L}_{f-1}$—Total molal rate of flow of liquid onto the feed plate; $\bar{L}_{f-1} = L_{f-1} + L_F$.

L_F—Molal rate of flow of the liquid part of the feed. For boiling point liquid and subcooled feeds, $L_F = F$, and for dew point vapor and superheated feeds $L_F = 0$.

M_D, M_B—Quantities appearing in the enthalpy balances for the rectifying and stripping sections, respectively; defined below Equation (23).

N—Total number of plates in the column. The plates are numbered down from the top with the top being 1, the plate above the reboiler N, and the reboiler N + 1.

Q_c—Condenser duty; net rate of heat removed by the condenser.

Q_R—Reboiler duty; net rate of heat input by the reboiler.

s—An integer used for counting.

S_{ji}—Stripping factor for component i and for plate j; definition follows Equation (19).

T—Temperature in ° F.

v_{ji}—Molal rate at which component i in the vapor state leaves plate j.

$\bar{v}_{fi}$—Molal rate at which component i in the vapor state enters plate f — 1.

v_{Fi}—Molal rate of flow of component i in the vapor part of a partially vaporized feed.

V_j—Total molal rate of flow of vapor from plate j.

$\bar{V}_f$—Total molal rate at which vapor enters plate f—1; $\bar{V}_f = V_f + V_F$.

V_F—Molal rate of flow of the vapor part of the feed. For boiling point liquid and subcooled feeds $V_F = 0$, and for dew point vapor and superheated feeds $V_F = F$.

x_{Bi}—Mole fraction of component i in the bottoms.

x_{Fi}—Mole fraction of component i in the liquid part of a partially vaporized feed.

x_{ji}—Mole fraction of component i in the liquid leaving plate j.

X_{Di}—Mole fraction of component i in the distillate regardless of state in which it is withdrawn.

X_{Fi}—Total mole fraction of component i in the total feed F.

y_{Fi}—Mole fraction of component i in the vapor part of a partially vaporized feed.

y_{ji}—Mole fraction of component i in the vapor leaving plate j.

α—Relative volatility of individual components; $\alpha_i = K_i/K_k$.

Θ—A correction factor; defined by Equation (1).

Θ_r—Positive root of Equation (5).

λ—A correction factor; $\Theta = 1/\lambda$.

Σ—Denotes a sum; $\sum_{i=1}^{c}$ = sum from i = 1 through c.

ϕ_i, Φ_i—A product and sum of products, respectively; defined with Equation (29).

Ω—A function defined by Equation (15).

Subscripts

a—Assumed value.

B—Bottom product.

ca—Calculated value.

co—Corrected value.

D—Top product.

F—Feed.

f—Feed plate.

i—Component number, i = 1 to i = c.

j—Plate number; for the condenser j = 0, for the top plate j = 1, for the feed plate j = f and for the reboiler j = N + 1.

k—Base component.

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TO BE CONTINUED

Predict RVP of Blends Accurately

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A NEW CALCULATION METHOD is given for predicting Reid vapor pressures of fuel blends. Direct allowance is made for the partial vaporization of the sample in the test chamber, and for non-ideal gas behavior. Data on a wide variety of test blends confirm the accuracy of the method.

The Reid vapor pressure test[1] is widely used as a criterion for blending of gasoline and other fuels. Accurate prediction of fuel compositions having a specified Reid vapor pressure is therefore necessary in refinery scheduling and economic studies. This need prompted the study reported here.

The specifications of the Reid test will be referred to frequently. The main steps in the Reid test, for ordinary motor fuels, are as follows[1]:

1. The sample container is cooled to 32-40 F. After saturating the liquid with air, a sample is displaced from the container into a 100 cc. liquid chamber also at 32-40 F.
2. The liquid chamber is connected to a chamber filled with water-saturated air at atmospheric pressure and a known temperature, preferably 100 F, to form a sealed constant-volume bomb. The volume of the air chamber, neglecting the attached Bourdon pressure gage, is 4.0 $\pm$0.2 times that of the liquid chamber.*
3. The bomb is brought to 100 $\pm$0.2 F. and the air chamber pressure is periodically read. The equilibrium air chamber pressure in psig, corrected to an initial air chamber temperature of 100 F., is reported as the Reid vapor pressure (Rvp) of the sample in *pounds*.

The above procedure amounts to a measurement of the equilibrium pressure in a constant-volume partial vaporization of the sample into air. The test conditions were chosen to simulate the partial vaporization of a fuel which occurs before it enters the fuel line of the engine in normal use, and thus to facilitate the desired correlation of Reid vapor pressure with vapor-locking tendency.

Using the above information on the Reid test, limited information on fuel specifications, and standard thermodynamic methods, Reid vapor pressures of fuel blends can be predicted accurately from data on the components. This approach gives more dependable results, and a better understanding, than can be obtained by strictly empirical methods.

Basic Theory. It is convenient to express vapor-liquid equilibrium data in the form

$$(K\pi)_i \gamma_i = \frac{\pi y_i}{x_i} \qquad (1)$$

where $(K\pi)_i$ is an ideal vaporization equilibrium constant and γ_i is an activity coefficient used to allow for deviation from ideal behavior.

* Some authorities now favor an increase in the volume ratio above 4.0. The volume ratio, *N*, is therefore included as a variable in the following treatment.

By means of Equation (1) and appropriate material balances one can show that the equilibrium liquid composition in the Reid test is given by the following flash equilibrium equation:

$$x_i = \frac{F_i}{L + G K_i \gamma_i} \qquad (2)$$

In the Reid test, the gas volume V_G is known quite accurately and G, the moles of gas, is therefore evaluated as follows:

$$G = \frac{\pi V_G}{z_G RT} \qquad (3)$$

The equilibrium liquid composition is then given by

$$x_i = \frac{F_i}{L + \dfrac{V_G}{z_G RT} (K\pi)_i \gamma_i} \qquad (4)$$

The equilibrium system pressure, π, is the bubble-point pressure of the equilibrium liquid, and may be computed as follows:

$$\pi = \pi \Sigma y_i = \Sigma (K\pi)_i \gamma_i x_i \qquad (5)$$

where the summation includes all components present in the system.

Liquid and Vapor Quantities. To avoid unduly complicated calculations, we will ignore the presence of air and water vapor in the Reid test. That is, all calculations will be made as if the sample were actually charged to an evacuated bomb and the equilibrium *absolute* pressure were reported as the Reid vapor pressure. This hypothetical model of the Reid test is much simpler to analyze than the actual test, and exhibits substantially identical blending behavior.

It will also be assumed, in correcting the phase volumes for thermal expansion and evaporation, that the volatile components have the molal density of butanes and the non-volatile components have the thermal expansion characteristics of *n*-octane. These assumptions are adequate for the small corrections involved.

Since fuel densities are commonly measured at 60 F., all calculations here are made on a basis of one barrel of sample measured at 60 F. Using density data for *n*-octane, the following liquid-phase volumes are obtained, neglecting evaporation:

At charging temperature	(35 F.)	:	0.986 barrel
At datum temperature	(60 F.)	:	1.000 barrel
At final temperature	(100 F.)	:	1.024 barrel

If the gas chamber has a volume N times that of the liquid chamber, or 0.986 N barrels on the basis adopted here, correction for the liquid expansion of 0.038 barrels gives the following gas-phase volume at 100 F., neglecting evaporation:

$$\mathring{V}_G = 0.986\ N - 0.038 \text{ barrel} \qquad (6)$$

For the present Reid test, with N = 4.0, one obtains $\mathring{V}_G = 3.91$ barrels.

The final gas-phase volume, corrected for evaporation, is

$$V_G = \mathring{V}_G + V_G \frac{z_L}{z_G} \tag{7}$$

where z_G and z_L are the compressibility factors of the evaporated material considered as gas and liquid, respectively, at the final system temperature and pressure. This equation is based on the assumption that volumes are additive in both phases. Rearrangement of Equation (7) gives

$$\frac{V_G}{z_G} = \frac{\mathring{V}_G}{z_G - z_L} \tag{8}$$

Analysis of thermodynamic tables for isobutane[2] and n-butane[3] at 100 F. gives the following approximate equation, valid within 0.7 percent up to the saturation pressures:

$$z_G - z_L \doteq 1 - 0.0021\,\pi \tag{9}$$

where π is in pounds per square inch absolute (psia). Pure butanes are stable only as vapor at these conditions; liquid densities in solution were assumed constant at the saturation values in developing this equation.

For the air- and water-free model of the Reid test, the system pressure and the Reid vapor pressure are equivalent. Making this substitution, and combining Equations (6), (8), and (9), one obtains the following useful function for the flash calculation:

$$C = \frac{V_G}{z_G RT} = 0.000935\ \frac{0.986\,N - 0.038}{1 - 0.0021\,Rvp} \tag{10}$$

C is tabulated as a function of Rvp in Table 1 for the present Reid test in which N = 4.0.

The equilibrium moles of gas, G, may be found from the related equation

$$G = (C)\ (Rvp) \tag{11}$$

and the flash equation (4) may then be written, to a good approximation, as follows:

$$x_i = \frac{F_i}{F - G + C\,(K\pi)_i\,\gamma_i} \tag{12}$$

where $(K\pi)_i$ is in psia. Values of x_i computed from Equation (12) usually add to within 1 percent of the required total of unity, and are accurate enough for Reid vapor pressure calculations if Equation (5) is modified to read:

$$Rvp = \frac{\Sigma\, x_i\,(K\pi)_i\,\gamma_i}{\Sigma\, x_i} \tag{13}$$

Use of Equation (13) is equivalent to a proportional adjustment of all the x_i values to the correct total of unity. This adjustment is so effective that Equation (12) can be simplified further without significant error:

$$x_i \doteq \frac{F_i}{F + C\,(K\pi)_i\,\gamma_i} \tag{14}$$

Substitution of Equation (14) for (12) is recommended, for the present Reid test, as experience indicates that this simplification will seldom alter the calculated Reid vapor pressure by more than 0.01 pound. If a higher volume ratio, N, should come into use, the discrepancy might increase to a significant value and Equation (12) would then be preferred.

TABLE 1—Values of C for Equation (12) or (14) for the Reid Test with N = 4.00

RVP, lb.	C, (lb. mole) (bbl)$^{-1}$ (psia)$^{-1}$
0	0.00365
5	0.00369
10	0.00373
15	0.00377
20	0.00381

Estimation of Kπ Values. The pressure dependence of $(K\pi)_i$ has been computed for several light hydrocarbons using the equation of Souders, Selheimer and Brown[4] in the form

$$(K\pi)_i = P_i\, e^{\int_{P=P_i}^{P=\pi} (1 - z_{iG} + z_{iL})\, d \ln P} \tag{15}$$

Recommended values of $(K\pi)_i$ obtained by this method are given in Table 2 for a total pressure of 10 psia, which corresponds to a Reid vapor pressure of 10 pounds on the basis of calculation adopted here.

Equation (15) predicts a nearly linear variation of $\ln(K\pi)_i$ with pressure at low pressures. At the conditions of interest here (100 F. and moderate pressures), we represent $(K\pi)_i$ by the simpler and nearly equivalent relation

$$(K\pi)_i = \mathring{P}_i\, e^{0.0021\ Rvp} \tag{16}$$

in which Rvp has been substituted for the system pressure, and $\mathring{P}_i$ represents the value of $(K\pi)_i$ at the reference state of zero blend Reid vapor pressure. Values of $\mathring{P}_i$ for propane and butanes are given in Table 2; values for other fuel components are to be determined by the relation

$$\mathring{P}_i = Rvp_i\, e^{0.0021\ Rvp_i} \tag{17}$$

which is given numerically in Table 3.

Equations (16) and (17) give dependable effective Kπ values at Reid test conditions for all C_{4+} hydrocarbons and fuel stocks regardless of boiling range or butane content. For pure compounds and narrow-boiling cuts, the Kπ values so determined agree closely with other ideal K and Kπ correlations[6,7] if the blend Reid vapor pressure is considered as the total pressure in making comparisons. Wide-boiling cuts can be considered as single components with excellent accuracy if $K\pi_i$ is evaluated from Rvp_i in the above manner, since the fractionation of such cuts in the test is then included in the effective value of $(K\pi)_i$.

Substitution of the bubble-point pressure, P_i, of a liquid for its Reid vapor pressure, Rvp_i, is not permissible, except in the case of very narrow-boiling or nonvolatile fractions, for which the fractionation in the Reid test is negligible as shown by Equation (14). For fractions in which all components boil above 170 F., the Reid vapor pressure and the bubble-point pressure at 100 F. agree within about 1 percent.

The activity coefficient, γ_i, corresponding to the $(K\pi)_i$ values defined above may be considered unity for ideal solutions as defined by the Lewis and Randall fugacity rule. For lack of data, γ_i has been taken as unity for all components in all calculations reported here.

The advantage of referring the Kπ values to zero pressure becomes evident in the bubble-point pressure

calculation. Combination of equations (13) and (16) gives

$$Rvp = \frac{\Sigma x_i \gamma_i \overset{\circ}{P}_i e^{0.0021\ Rvp}}{\Sigma x_i} \quad (18)$$

or

$$\overset{\circ}{P} = \frac{\Sigma x_i \gamma_i \overset{\circ}{P}_i}{\Sigma x_i} \quad (19)$$

where $\overset{\circ}{P}$ is the reference $K\pi$ of the blend, defined analogously to $\overset{\circ}{P}_i$:

$$\overset{\circ}{P} = Rvp\ e^{-0.0021\ Rvp} \quad (20)$$

Equations (17) and (20) are identical in form, and are represented by the same numerical relation in Table 3. The advantage of using Equation (19) rather than (13) is that $\overset{\circ}{P}_i$, unlike $(K\pi)_i$, is independent of the Reid vapor pressure of the blend.

The flash calculation is also simplified by using $\overset{\circ}{P}_i$.

TABLE 2—Properties of Light Hydrocarbons

	P_i at 100 F. (psia)	$(K\pi)_i$ at π = 10 psia and 100 F. (psia)	$\overset{\circ}{P}_i$ (psia)	ρ_{mi} as liquid at 60 F, 1 atm (mols/bbl)
Propane[5]	188.7	149	146	4.03
i-Butane[2]	71.9	63.7	62.4	3.39
n-Butane[3]	51.6	47.3 *	46.3 **	3.52

* Computed from vapor pressure and compressibility data from the references cited, by Equation (15).
** Computed from Equation (16) and the given $K\pi$ values.

TABLE 3—Functions for Use With Reference K_π Values in the Reid Test With N = 4.0

Reid Vapor Pressure (lb.)	$\overset{\circ}{P}$ At Given Rvp or $\overset{\circ}{P}_i$ At Given Rvp_i (psia)	H At Given Rvp (lb. moles) $(bbl.)^{-1}$ $(psia)^{-1}$
0	0.00	0.0036
1	1.00	0.0037
2	1.99	
3	2.98	
4	3.97	
5	4.95	
6	5.92	
7	6.90	0.0038
8	7.87	
9	8.83	
10	9.79	
11	10.75	
12	11.70	
13	12.65	0.0039
14	13.59	
15	14.53	
16	15.47	
17	16.40	
18	17.33	
19	18.26	0.0040
20	19.18	
21	20.10	
22	21.01	
23	21.92	
24	22.82	
25	23.72	0.0041
26	24.62	
27	25.51	
28	26.40	
29	27.29	
30	28.17	0.0042

Combination of Equations (14) and (16) gives

$$x_i = \frac{F_i}{F + H \gamma_i \overset{\circ}{P}_i} \quad (21)$$

where

$$H = C\ e^{0.0021\ Rvp} = \left(\frac{0.000922\ N - 0.000036}{1 - 0.0021\ Rvp} \right) e^{0.0021\ Rvp} \quad (22)$$

H is given as a function of Rvp in Table 3. The same value of H applies to all components in a given blend.

The results indicate that, even without allowance for non-ideal solution behavior, the $\overset{\circ}{P}$ method gives best over-all agreement with the data used here. Due in part to the neglect of non-ideal behavior, the systematic deviations are fairly large for all methods, and the only clear-cut comparison is that for the blends of light hydrocarbons in weathered crudes. The latter results clearly show the fundamental correctness of using mol fractions, $(K\pi)_i$ values (or the equivalent calculation involving $\overset{\circ}{P}_i$ values), and a flash calculation as is done in the $\overset{\circ}{P}$ method.

Allowance for activity coefficients as functions of composition would greatly improve the accuracy of the $\overset{\circ}{P}$ method. It is believed that such allowance would give predictions approaching the experimental accuracy, and virtually eliminate systematic deviations such as have been observed for blends of n-butane with highly aromatic stocks (benzene, toluene, heavy fluid gasoline, and catalytic reformate). It is hoped that those who have access to more extensive data will undertake the correlation of these activity coefficients, or make their data available for this purpose.

Comparison With Other Methods. Table 4 summarizes the results of a calculation study in which various methods for predicting Reid vapor pressures were compared with data on 67 test blends ranging from 4.4 to 14.45 Rvp. Results are given for the following methods:

1. The $\overset{\circ}{P}$ method of this article.
2. Volumetric averaging of Reid vapor pressures, using the blend composition rather than the equilibrium liquid composition in the Reid test.
3. The method of Haskell and Beavon,[8] which is equivalent to Method 2 except that, for butanes, variable "blending vapor pressures" are used depending on the Reid vapor pressures of the butane fraction and the debutanized blend.
4. Molar averaging of Reid vapor pressures, using the blend composition.

TABLE 4—Comparison of Methods for Prediction of Blend Reid Vapor Pressures

Data		Recommended $\overset{\circ}{P}$ Method ($\overset{\circ}{P}$ Method)	Method 2 (Volumetric av. Rvp)	Method 3 (Haskell and Beavon) (8)	Method 4 (Molar av. Rvp)	Method 5 (Molar av. $\overset{\circ}{P}$ as charged)
Butanes in Gasoline Base Stocks (36 blends)	Av. deviation*	—0.07	0.61	—0.18	—1.00	—0.39
	Std. deviation*	0.84	0.98	0.72	1.39	0.95
Casinghead in Gasoline Base Stocks (12 blends)	Av. deviation*	—0.29	0.14	0.14	—0.50	—0.37
	Std. deviation*	0.42	0.35	0.35	0.59	0.48
n-Butane in Light Fluid Gasoline and Catalytic Reformate (12 blends)	Av. deviation*	0.76	1.20	0.67	0.15	0.55
	Std. deviation*	0.96	1.39	0.79	0.44	0.76
Butanes and Casinghead in Crudes (7 blends)	Av. deviation*	—0.15	2.59	2.25	—1.35	—0.71
	Std. deviation*	0.26	2.80	2.42	1.49	0.98
All Data (67 blends)	Av. deviation*	0.03	0.84	0.28	—0.74	—0.25
	Std. deviation*	0.76	1.30	1.01	1.17	0.83

* Deviations were computed as observed Rvp minus Predicted Rvp, in pounds.

5. Molar averaging of $\overset{\circ}{P}_i$ using the blend composition. This is equivalent to the recommended method except that the flash calculation is omitted.

Activity coefficients were taken as unity in Methods 1 and 5; they do not appear in the other methods.

EXAMPLE

Calculate the volume fraction, v_1, of n-butane required to pressure the following gasoline stock, component 2 , to 10.0 Rvp:

$$Rvp_2 = 4.0 \text{ lb.}$$
$$\rho_{M2} = 2.76 \text{ lb. moles/bbl.}$$

Assume $\gamma_i = 1.0$ for both components.

Solution: Equation (19) may be rearranged to give

$$\Sigma x_i (\gamma_i \overset{\circ}{P}_i - \overset{\circ}{P}) = O$$

Evaluating x_i by Equation (21) and making the substitution $F_i = v_i \rho_{Mi}$ gives

$$\sum \frac{v_i \rho_{Mi}}{F + H \overset{\circ}{P}_i \gamma_i} (\gamma_i \overset{\circ}{P}_i - \overset{\circ}{P}) = O \qquad (23)$$

in which all quantities except v_i and F are given or obtainable from Tables 2 and 3. Estimation of F , the total moles per barrel in the finished blend, and taking $\gamma_1 = \gamma_2 = 1.0$, enables one to solve Equation (23) for v_1. Accurate estimation is not necessary; for example, the obviously inaccurate estimate, F = 2.5 lb. moles/bbl., permits the following numerical solution of Equation (23):

$$v_1\left[\frac{3.52}{2.5 + (0.0038)(46.3)}(46.3 - 9.79)\right]$$
$$+ (1 - v_1)\left[\frac{2.76}{2.5 + (0.0038)(3.97)}(3.97 - 9.79)\right] = O$$

from which one obtains the tentative solution $v_1 = 0.1173$. This can be checked by calculating a new F value:

$$F = (0.1173)(3.520) + (1 - 0.1173)(2.76)$$
$$= 2.85 \text{ lb. moles/bbl.}$$

Solution of Equation (23) with the revised F value gives

$$v_1 = 0.1166$$

The first calculation was therefore correct within the accuracy of the method. Since F can usually be estimated more accurately than was done here, Equation (23) gives a direct solution in most practical cases. Iteration may be necessary if activity coefficients are given as functions of composition.

The insensitivity of the unknown compositions in Equation (23) to the assumed value of F is due to the fact that F greatly exceeds $H\overset{\circ}{P}_i$ for butanes and all heavier components. This makes the denominators in Equation (23) nearly proportional to F, so that F almost factors out of the equation. The bubble-point equations, (13) and (19), are similarly insensitive to the values of F and C or H used in making the flash calculation, as long as the same values are used consistently for all components.

About the Author

Dr. W. E. Stewart is an associate professor at the University of Wisconsin, where he teaches and supervises graduate research on thermodynamics, fluid mechanics, heat and mass transfer, reaction kinetics and statistics. He was a project chemical engineer with Sinclair Research laboratories from 1950 until 1956, when he joined the University. Dr. Stewart has B.S. and M.S. degrees in chemical engineering from the University of Wisconsin and a Sc.D. degree from M.I.T. He is a consultant for Sinclair Research and Engelhard Industries, Inc., in the fields of catalysis and petroleum processing.

NOMENCLATURE

C	Coefficient in flash equations (12) and (14).
F	Density of blend as saturated liquid at 60 F. (lb. moles/bbl.)
F_i	Pound-moles of component i per barrel of liquid blend at 60 F. $= v_i \rho_{Mi}$
G	Pound-moles of sample evaporated in the Reid test per barrel of liquid blend at 60 F.
H	Coefficient in flash equation (21).
$(K\varpi)_i$	Ideal vapor-liquid equilibrium constant $= K_i \varpi$ (psia)
L	Pound-moles of residual liquid in the Reid test per barrel of liquid sample at 60 F.
N	Ratio of gas chamber volume to liquid chamber volume in the Reid test.
P	Total pressure (as variable of integration in Equation (15) (psia).
P_i	Vapor pressure of component i
$\overset{\circ}{P}_i$	Reference value of $(K\varpi)_i$ at zero blend Rvp (psia)
$\overset{\circ}{P}$	Value of $\overset{\circ}{P}_i$ for total blend when considered as a component for further blending (psia)
R	Gas constant.
Rvp	Reid vapor pressure of blend (lb.)[1]
Rvp_i	Reid vapor pressure of component i (lb.)[1]
T	Absolute temperature.
V_G	Final gas volume in the Reid test (cubic feet per barrel of liquid blend at 60 F.)
$\overset{\circ}{V}_G$	Final gas volume calculated without allowance for evaporation, (cubic feet per barrel of liquid blend at 60 F.)
e	Base of natural logarithms.
ln	Natural logarithm.
v_i	Volume fraction of component i in blend at 1 atm. and 60 F.
x_i, y_i	Mole fractions of component i in liquid and vapor.
z_G, z_L	Gas-phase and liquid phase compressibility factors for the total gas-phase material in the Reid test (or the air-and-water-free model of the Reid test) (dimensionless).
z_{iG}, z_{iL}	Gas-phase and liquid-phase compressibility factors for pure component i at the given temperature and total pressure (dimensionless).
γ_i	Activity coefficient for component i (dimensionless).
ϖ	System pressure (psia).
ρ_{Mi}	Molar density of component i (pound-moles per barrel as liquid at 1 atm. and 60 F.)
Σ	Summation over all components considered. (Equations from (6) on neglect water and air as components).

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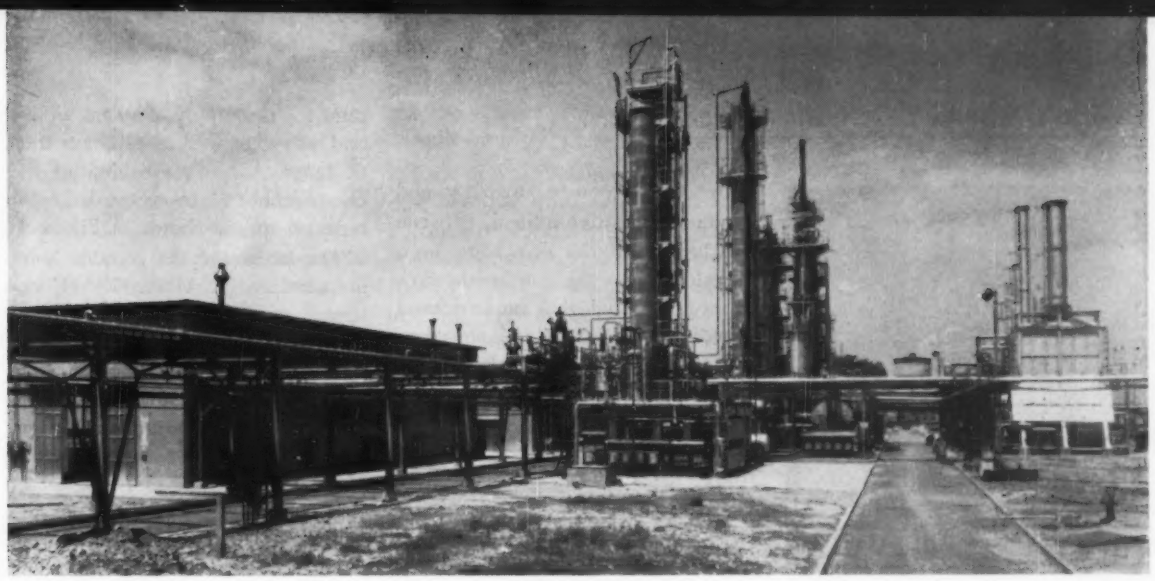

FIGURE 1—The crude distillation unit produces feed for the catalytic cracker.

World's Smallest Orthoflow Cracker

This smallest of Orthoflow catalytic crackers is being used for commercial production in Yugoslavia. Here is a report on how well it operates

Walter Fisher
Alexander Mosic
Emily Knezevic
Rafinerija Nafte Sisak
Yugoslavia

AFTER THREE YEARS of construction, the combination unit of the Sisak Petroleum Refinery in Yugoslavia went on stream in the late spring of 1956. This combination unit comprises a crude oil desalting plant, atmospheric and vacuum distillation units, catalytic cracking with annexed stabilizer and absorber for C_3 and C_4 hydrocarbons, gasoline treating, LPG washing, and an installation for H_2S absorption from the fuel gas.

The combination unit forms a single plant permitting continuous flow of products from one section to the next with no tanks for the intermediate hydrocarbon streams

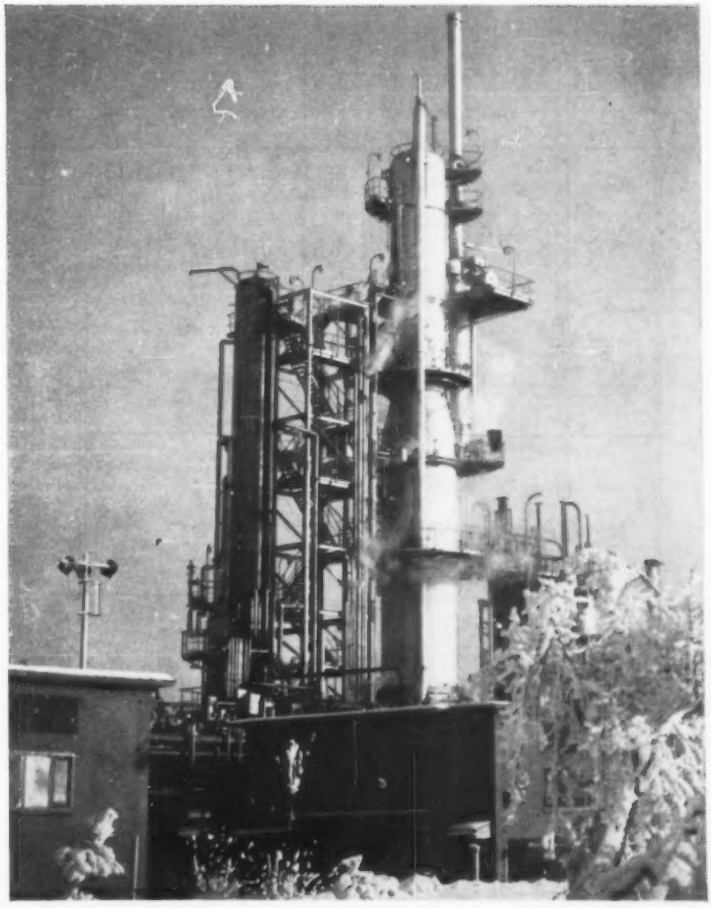

FIGURE 2—The Model A Orthoflow cracker has a fresh feed charge capacity of 1960 bpsd.

World's Smallest Orthoflow Cracker . . .

FIGURE 3—After eight months of operation, the reactor grid above the riser outlet was eroded severely.

between the crude topping and vacuum distillation units or between the latter and the cracking unit. In addition to the continuous flow of raw material and intermediates thereof, there are other innovations connecting the individual installations to form a composite plant. These installations include a central supply system for air operated controllers and measuring devices, a joint set of tube stills, a joint gas system for pressuring the equipment, a central control panel, a general pipe alley serving all parts of the plant with a common support system for piping, common slop and drain systems, a common fire protection system, general utilities systems for the supply of steam, power and water, as well as common traffic lanes. A bird's eye view of the compact, but not overcrowded combination unit is shown in Figure 1.

The plans for the erection were prepared by F. Uhde GmbH, designers of chemical installations at Dortmund, West Germany, in cooperation with the licensor, The M. W. Kellogg Company, New York, N. Y. The latter participated mainly in designing the Orthoflow Model A Catalytic Cracking plant employing fluidized beds of powdered catalyst. This section of the plant is shown in Figure 2. The combination unit was designed to process light crude oils into liquid fuels and gaseous byproducts. An Iraqi crude may be considered as a representative raw material for this unit. The plant was designed for handling 1100 metric tons a day (8,250 bpsd) of such crude, requiring a daily cracking capacity of 285 metric tons (1,960 bpsd). With this capacity, the Sisak Orthoflow Catalytic Cracker is the smallest known plant of its kind in the world.

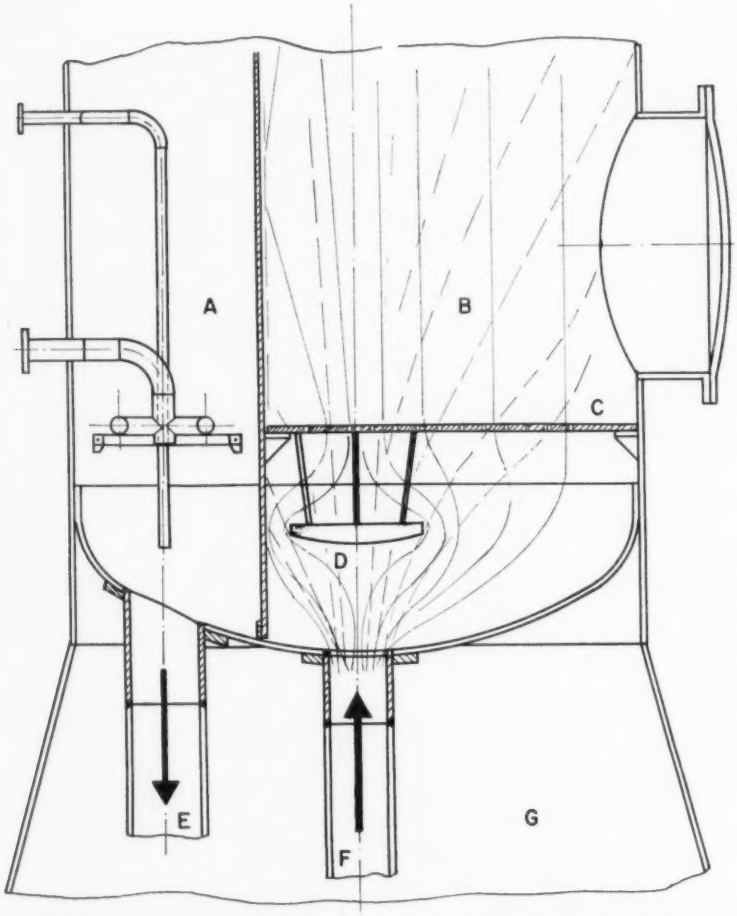

FIGURE 4—A thick plate now forms a deflector baffle for the oil vapors and catalyst jet. In this drawing, the parts are: stripper, A; reactor, B; grid, C; deflection plate, D; spent catalyst standpipe, E; regenerated catalyst riser, F; and upper portion of the regenerator, G.

Erosion. The substantially vertical flow pattern of the catalyst in the Orthoflow Model A design considerably reduces erosion problems encountered in catalytic cracking units. However, where erosion was encountered, corrective action was taken to minimize this problem.

After eight months of operation, the unit was inspected and erosion of the reactor grid above the riser outlet was noted. Figure 3 shows a portion of the bottom surface of the distributor grid and the effects of erosion. During the overhaul, rings have been inserted to restore the original diameter. In addition, a thick round plate was inserted between the riser discharge outlet and the grid (Figure 4). The inspection after subsequent eight month periods of operation, has proved the usefulness of this shield. It protected completely the grid from erosion. The deflector baffle was installed with the idea that it could be removed and replaced. During a next inspection of the unit, after eighteen months of

operation it was found that there was no necessity for such removal and replacement.

Erosion on the wall of the reactor indicated that a portion of the bed of catalyst was defluidized which permitted a relatively high velocity stream of reactant to channel through the catalyst and impinge upon the reactor wall. Inspection of the reactor after installation of the deflector baffle showed that this shield together with the grid affected substantially uniform distribution of the reactant over the cross-sectional area of the reactor, thereby alleviating the erosion problems previously encountered.

Erosion was encountered as in the case of other fluid catalytic cracking designs, in the seats and cones of the regenerated catalyst and the spent catalyst control valves (Figure 5). The experience with the valves at Sisak was similar to that obtained from a unit of similar size at Gelsenkirchen, Ruhr, West Germany. After 8 months of operation the same cone could be continued in service since no grooves were found on its surface. Should the grooves appear, the parts must be replaced

FIGURE 5—When the seat and cone of the spent catalyst valve becomes grooved, it is difficult to control the catalyst circulation.

TABLE 1—Summary of Orthoflow Fluid Catalytic Cracking Units*

COMPANY	LOCATION	DESIGN CAPACITY				Date On Stream
		Fresh Feed		Total Throughput		
		M ton/day	BPSD	M ton/day	BPSD	
Model A Orthoflow Units						
British American Oil Co	Edmonton, Alberta	290	2,000	510	3,500	July, 1951
Cities Service Oil Co	Ponca City, Oklahoma	1,220	8,350	1,490	10,939	Nov., 1951
Canadian Oil Refining Ltd	Sarnica, Ontario	1,210	8,300	2,050	14,027	May, 1952
Scholven-Chemie AG	Gelsenkirchen, W. Germany	730	5,000	730	5,000	July, 1953
Texas Company	Amarillo, Texas	810	5,578	1,415	9,706	Jan., 1955
Rafinerija nafte	**Sisak, Yugoslavia**	**285**	**1,960**	**485**	**3,332**	**May, 1956**
Model B Orthoflow Units						
Pure Oil Co	Toledo, Ohio	1,700	11,610	2,580	17,705	Oct., 1953
Pure Oil Co	Smiths Bluff, Texas	2,590	17,750	3,880	26,625	March, 1954
British American Oil Co	Clarkson, Ontario	1,700	11,610	2,540	17,415	June, 1954
Alantic Refining Co	Philadelphia, Pennsylvania	4,100	28,000	6,550	45,000	July, 1954
British Petroleum Co. Ltd	Kwinana, West Australia	1,820	12,500	1,820	12,500	March, 1955
North Star Oil, Ltd	St. Boniface, Manitoba	715	4,900	1,220	8,400	July, 1955
Champlin Refining Co	Enid, Oklahoma	1,310	9,000	1,970	13,500	Sept., 1955
Venezuela Gulf Refining Co	Puerto La Cruz, Venezuela	.....	.....	1,480	10,170	Dec., 1956
American Oil Company	Yorktown, Virginia	3,060	21,408	5,225	36,600	March, 1957
Tidewater Oil Company	Delaware City, Delaware	8,500	58,000	14,800	101,800	June, 1957
Petrobras	Bahia, Brazil	.....	.....	3,640	20,493	Nov., 1959 (?)
YPF	Lujan de Cuyo, Argentina	.....	.....	1,600	11,000	.....
ENAP	Concon, Chile	.....	.....	1,750	12,000	.....
British American Oil Co	Vancouver, British Columbia	.....	.....	1,310	9,000	.....
ANCAP	La Teja, Uruguay	.....	.....	728	5,000	.....

* Courtesy of "Kellogg International Corp.", London.

TABLE 2—Operational Conditions

	Design	A	B	C	D	E
Feedstock:						
Specific gravity at 60 °F	0.918	0.896	0.899	0.896	0.878	0.900
Characterization factor (UOP)	.....	11.85	12.11	12.00	11.80	11.78
Fresh feed, BPSD	1960	1885	2182	1786	1810	2000
Throughput ratio	1.7	1.6	1.4	1.7	1.7	1.8
Reactor temperature, F	900	887	882	882	900	887
Reactor bed density, lb. per cu. ft	35.0	28.0	25.0	26.0	23.7	25.0
Reactor bed height, feet	17.0	15.0	13.5	20.0	25.0	24.0
Catalyst hold-up in the reactor, short tons	13.0	9.2	7.3	11.3	13.5	13.0
Catalyst hold-up in the stripper, short tons	3.2	2.7	1.7	3.7	5.0	4.4
Space velocity, wt/hr/wt	1.75	2.22	2.80	1.83	1.85	1.85
Catalyst to oil ratio in the riser line, wt/wt	10.0:1	9.0:1	6.05:1	8.8:1	6.34:1	6.26:1
Severity factor (hour. wt cat) / (wt oil)	5.80	4.05	2.16	4.80	3.44	3.38
Catalyst inventory in the regenerator, short tons	15.0	22.3	27.8	30.6	33.4	25.9
Catalyst inventory in the converter, short tons	31.0	34.0	37.0	45.5	51.0	43.5
Regenerator bed height, feet	14.0	13.5	19.5	14.5	16.0	16.5
Regenerator temperature, F	1067	1100	1103	1108	1096	1076
Yields, per cent by weight						
Dry gas, $H_2+C_1+C_2$	10.00	5.45	6.00	3.93	4.56	7.24
LPG, C_3+C_4	9.60	13.80	7.25	12.73	20.30	8.05
Gasoline, EP 410 F	39.90	42.80	23.90	45.50	38.76	44.97
Tractor fuel	2.90	7.00	2.40	4.22	0.00	7.20
Light gas oil	22.70	0.00	14.80	12.07	20.32	10.11
Heavy gas oil	0.00	7.00	18.20	0.00	0.00	0.00
Decanted oil	5.45	15.80	18.95	13.83	8.03	14.29
Coke	9.45	8.15	8.50	7.72	8.03	8.14
Conversion						
Per cent by volume	70.00	70.00	40.20	70.71	72.11	71.47
Per cent by weight	68.95	70.20	47.20	69.88	71.65	69.12

since it then becomes difficult to control the catalyst circulation. However, the ring in the same period of operation developed grooves in its surface and was considered as worn out requiring replacement.

Operational Conditions. Since the Sisak Orthoflow was designed for a daily fresh feed charge rate of 285 metric tons (1,960 bpsd), the design throughput ratio in the reactor amounts to 1.7, which means that the total throughput, fresh feed plus recycle, runs up to 485 metric tons a day (3,332 bpsd). The general operational conditions differed very little from those anticipated by the design. On the whole, the working conditions proved to be more favorable than anticipated. Table 2 compares the planned and experienced values of some typical process variables.

One interesting feature of the Orthoflow design is the possibility to maintain a relatively large amount of catalyst in the regenerator. Accordingly it becomes easier to maintain the temperature within desired operating limits. In addition, because of the somewhat lower temperature employed, low yields of coke, oil quality, and limited recycle of slurry oil into the reactor, permits burning of coke even when running the plant at peak load without the introduction of cooling water into the regenerator. In rare and short periods of operation when water cooling became necessary, the catalyst showed a considerable drop in activity. However, the method of severe cooling is indispensable in those cases when the catalyst by some disturbance becomes black requiring the burning of extremely large quantities of coke. Maintaining a relatively deep bed of catalyst in the regenerator proved to be an exceptionally good remedy against the appearance of black catalyst. Also a reduction of throughput for a short time is the most convenient method of appeasing this trouble. By noticing the blackening in proper time—and a careful operator of the converter will hardly ever fail to see it from the change of the differential pressure on the riser line valve—the burning of the excessive coke can also be made under full load with simultaneous rising of the temperature from 580 C. (1,075 F.) to 610 C. (1,130 F.) and intensive cooling of the settling space with condensed water. When proceeding so, the crucial moment arises when the catalyst finally becomes white, when the temperature of the regenerator drops rapidly due to the loss of fuel, which requires the flow of cooling water to be discontinued. Intensive development of steam thus being stopped, the pressure in the regenerator drops so quickly that the slide valve might not be able to follow, sometimes not even with the aid of manual operation. Therefore heavy disturbances with the circulation of catalyst occur. Usually an abrupt fall-through of the catalyst into the regenerator involves an exaggerated load upon the shrunken reactor bed, thus inducing reblackening. The worst consequence of the loss of pressure in the regenerator is the reverse flow of the catalyst requiring at once to stop the feed of raw gasoil. By vigilant operation these disturbances or upsets may be virtually eliminated.

In the course of the past two years power failures occurred twice which caused the stoppage of pumps and the turboblower. However, during both of these power failures the staff succeeded in resuming the operation of the converter although the interruptions lasted as much as 10 and 19 minutes respectively. The capability of this converter design to resume normal operation after such a situation is evidence of the operationally advanced design of this unit. ##

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Knezevic

Walter Fisher received a degree in chemical engineering from the University of Vienna in 1924. Before World War II he was technical manager of Yugoslavia's Sisak refinery, affiliated with the Royal Dutch Shell group. During the war he was in a Nazi concentration camp. Liberated later by friends, he got the protection of the partisans on the liberated territory. After 1945 he went on to lead reconstruction of the Sisak refinery. The next few years he spent as chief chemist at the Institute of Petroleum at Zagreb. From 1954 until his death in September, 1957, Fisher was at Sisak supervising expansion programs. Famous in European engineering circles, he was awarded Yugoslavia's Labor Award in May, 1957.

Alexander Mosic received a chemical engineering degree from the University of Belgrade, Yugoslavia, in 1947. After serving in the Yugoslav Liberation Army, he worked in the alkali industry at Lukavac, Bosnia, where he was chief chemist from 1949-52. He then joined the Sisak refinery as assistant production superintendent, and directed startup of Sisak refinery's first pipe still. Mosic also directed operation of the refinery's combination crude unit in the first two years. He has authored a number of technical papers for Yugoslav journals.

Emily Knezevic received a chemical engineering degree from the University of Zagreb, Yugoslavia, in 1950, and became laboratory chief at the Katran plant, Zagreb. She later became assistant laboratory chief at the Sisak refinery. Mrs. Knezevic has done research on gasoline copper sweetening, and a systematic investigation on sulfur content of Yugoslav crudes. She is a member of the Asphalts committee, Yugoslav Association of Petroleum Producing and Refining Enterprises.

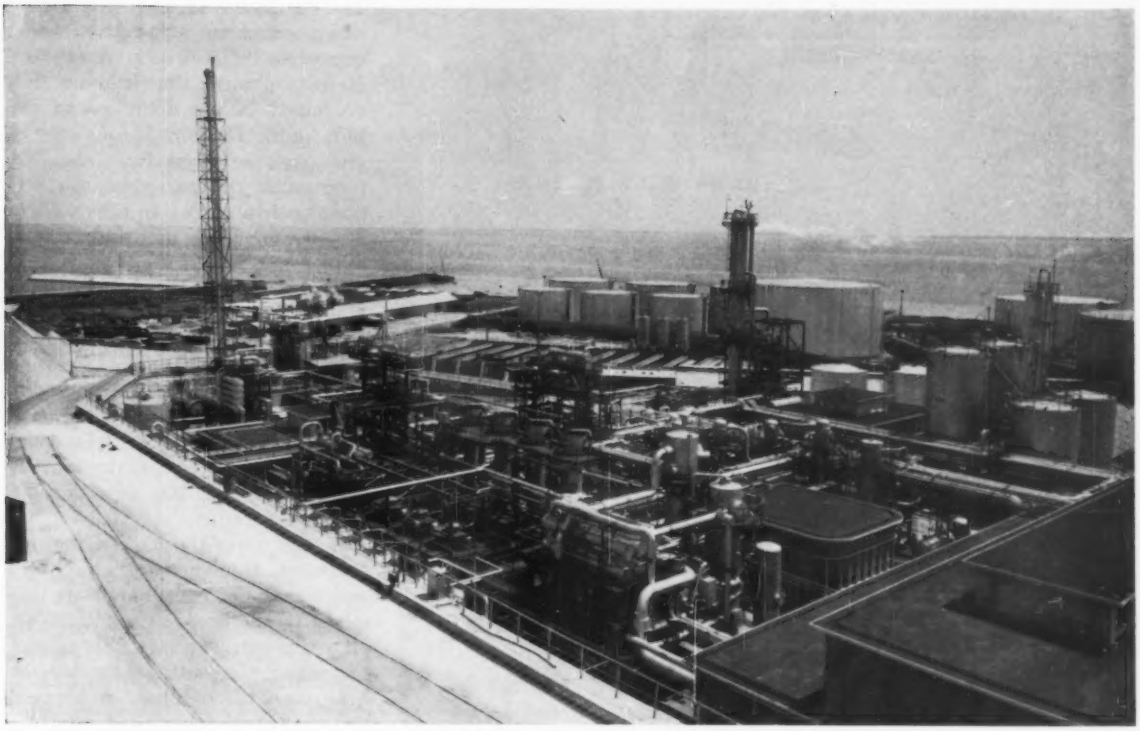

FIGURE 1—Investment costs are low because almost the whole plant can be constructed from ordinary carbon-steel.

SO_2 Extraction Plant Has Flexibility

This extraction plant in Lisbon can treat a variety of stocks. It also makes its own solvent by burning refinery hydrogen sulfide

THE SO_2 EXTRACTION plant at the Lisbon refinery of the S.A. Concessionária da Refinação de Petróleos em Portugal (SACOR) was constructed by the Edeleanu Company m.b.H., Frankfurt/Main, Germany. This plant has a number of desirable features:

- The unit is extremely flexible as it is capable of treating kerosine, gas-oil as well as lube-oils.
- The utility requirements combined with very small solvent losses maintain operating expenses at an extremely low level.
- The solvent used (SO_2) is cheap and is easily produced from hydrogen sulfide; the latter is available in nearly all plants having cat crackers or desulphurization units. The production of SO_2 can, as at the SACOR refinery, be combined with the manufacture of small amounts of sulfuric acid.
- Investment costs for an SO_2-extraction unit are low, due to: (1) The use of a low-boiling solvent, (2) the solvent is used for direct cooling by evaporation, (3) practically the whole plant can be constructed using ordinary carbon-steel.

A general view of the plant is shown in Figure 1, and a flow diagram is given with Figure 2. Here is the way the plant operates:

The distillate fed to the plant must not carry over 0.005 percent by weight of water. Therefore, quantities in excess of this must be removed in some type of drying equipment. Kerosine and light gas-oils are dried over rock-salt, while the heavy gas-oil is dried by heating it in a small vacuum column. The

SO_2 Extraction Plant Has Flexibility . . .

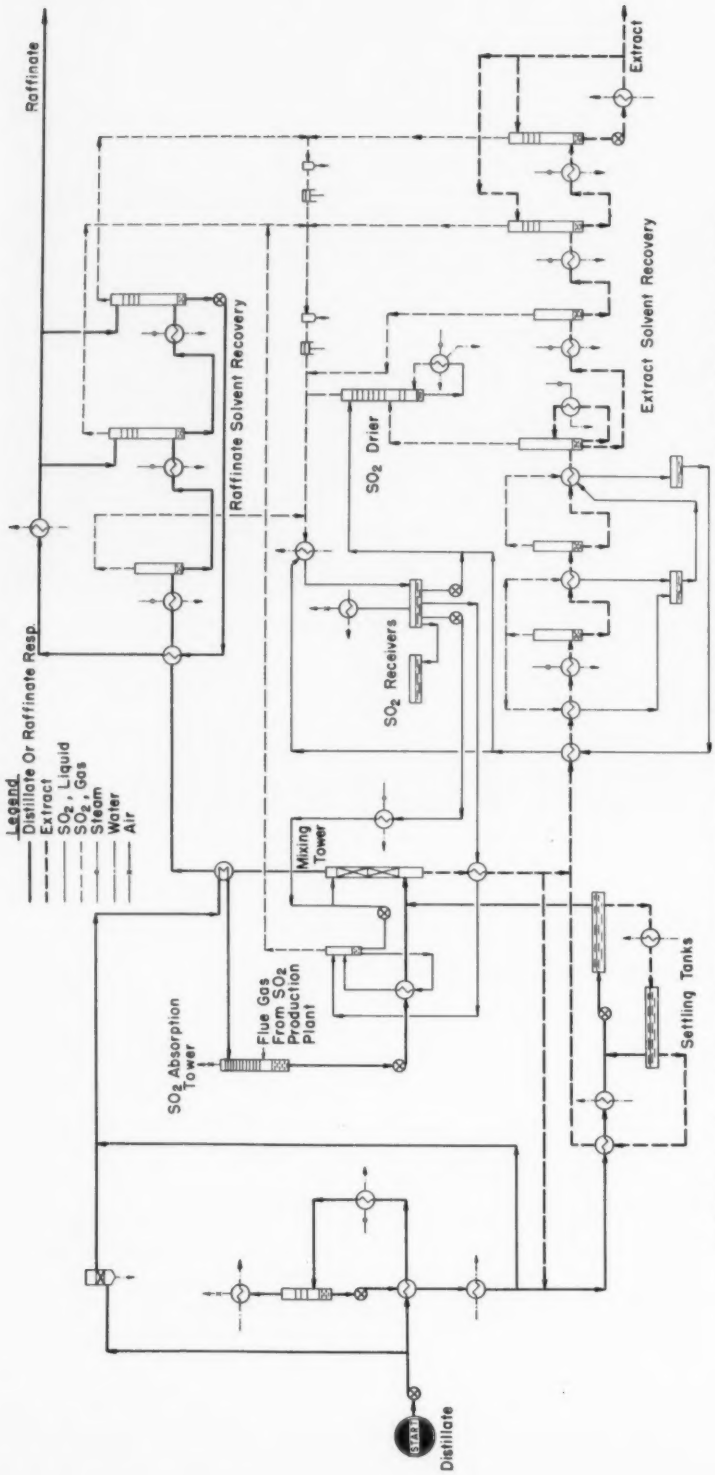

FIGURE 2—A multistage solvent recovery system and an SO_2 absorption tower are used to reduce solvent losses.

dry distillate—after being cooled down to ambient temperature—next enters the SO_2 absorption tower. Here it absorbs the make-up SO_2 contained in the dried gas of the SO_2 unit. The small amount of vent-gases removed from the SO_2 receiver is also passed to the SO_2 absorption tower to absorb the SO_2 contained therein and thereby reduce the SO_2-losses.

The distillate, charged with some SO_2, is cooled down to treating temperatures by evaporating the gas to about 14 F. in the case of kerosine or to about 32 F. for treating gas-oils. The liquid then enters the mixing or extraction tower, where the oil is contacted in counter-current flow with liquid SO_2 at about the same temperature.

In this tower the bulk of the unsaturated, aromatic hydrocarbons and high sulfur constituents are dissolved by the liquid SO_2 and drawn off as the extract phase. The extract containing the bulk of the solvent next passes through heat exchangers to a multistage solvent recovery system.

The raffinate containing some dissolved SO_2 leaves the top of the extraction tower, is preheated in heat exchangers and then freed from SO_2 in a three-stage evaporating system. The evaporator columns are equipped with tubular heaters heated by exhaust steam. The gas-oil raffinate leaves the plant as a final product. In the case of kerosine, the raffinate is finished in a copper sweetening unit.

The SO_2 vapors from the first evaporator stage for the raffinate pass directly to the SO_2 condenser. This operates, depending on the cooling water temperature, at a pressure of approximately 4-5 atmospheres.

The SO_2 vapors from the second evaporator stage are withdrawn by the SO_2 compressor and from there pass into the SO_2 condenser. The SO_2 vapors from the third and last stage are withdrawn by a vacuum pump.

The SO_2 from the extract drawn off from the bottom of the extraction tower is similarly recovered. The greater SO_2 quantities in the extract are utilized for heating purposes, this being accomplished by adding two pre-evaporators operating at about 15 and 10 atmospheres respectively. The vapors from these

preliminary stages are used in both cases for heating the next evaporator stage. The solvent-free extract goes either to storage or to the rerun unit.

The SO_2 vapors from the third extract evaporator pass by way of a drying column to the SO_2 condenser. Drying this partial stream of SO_2 vapors is sufficient to keep the water content of the total solvent low enough to avoid corrosion.

Lubricating oil distillates are dried by heating under vacuum and extracted in a system consisting of the mixing tower, mixing pump and two settlers. The extraction is a countercurrent process with a temperature gradient. The distillate enters the system through one of the settlers, where it is extracted at a medium temperature with the extract leaving the mixing tower. The extract from this first settler is cooled and enters a second settler. Here a pseudo-raffinate is separated and mixed with the feed charged to the first settler. The extract from the second settler passes to the evaporators. The solvent recovery unit is the same as used in the kerosine and gas oil extraction.

The raffinate from the first settler passes to the mixing tower, where it is extracted with fresh SO_2 at the highest temperature gradient. From the mixing tower the raffinate passes next to the three stage evaporator system, while the extract as mentioned above is cooled passing to the first settler.

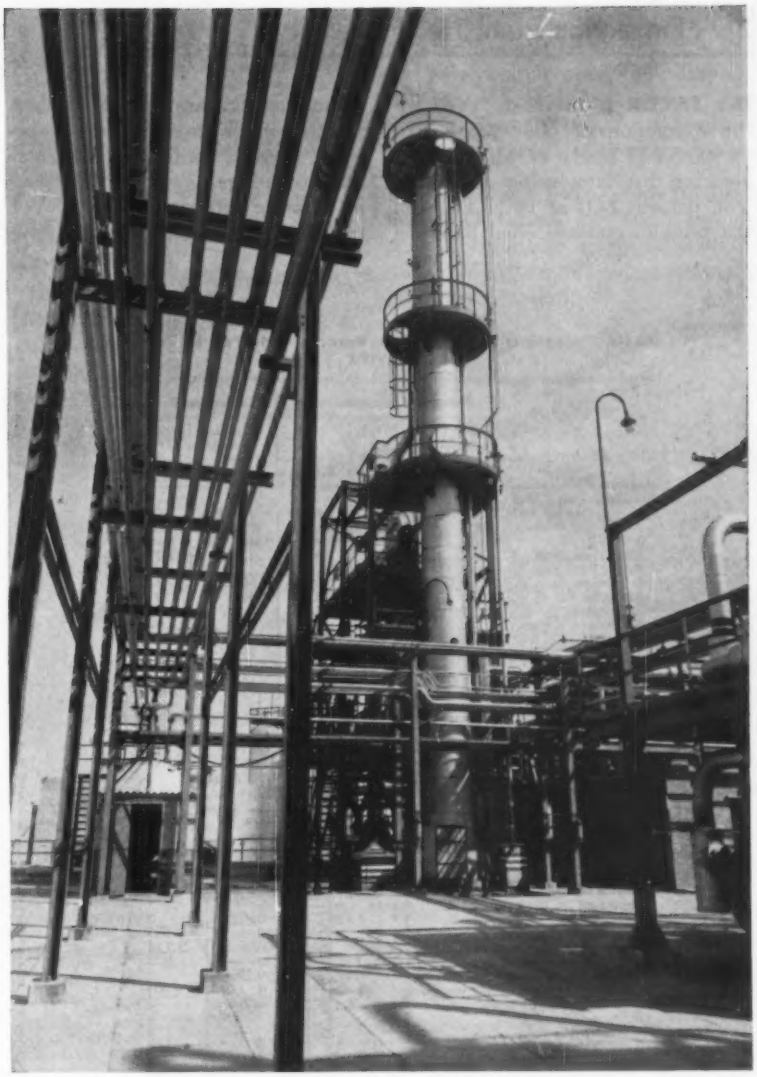

FIGURE 3—The extract from kerosine treating is split into a light cut for premium gasoline and a heavy cut for diesel oil.

The SO_2 production unit burns H_2S gas of a purity of 96-97 percent, in a small vertical furnace using a slight excess of air. Exit gases show a temperature of about 2,190 F. and contain 8-10 Vol. percent of SO_2. After being cooled to 35-37 F. by an air cooler, a scrubber and finally by evaporation of SO_2, the flue gases pass through a cartridge filter in which the last water-droplets are removed.

The gas is then dried over 98 percent sulfuric acid to a water-content of 0.02 percent. Between 85-90 percent of the dry flue gas passes to the absorption tower of the extraction plant where the SO_2 is completely absorbed by relatively large amounts of incoming kerosine. The remainder, or some 10-15 percent of the dry flue gas, is converted to SO_3, with vanadium pentoxide as catalyst. SO_3 gas is used to maintain the concentration of the sulfuric acid, used for drying the flue gas, at 98 percent. In that manner, the unit produces some quantities of 98 percent sulfuric acid which are used by the SACOR refinery for treating.

Valuable aromatics are contained in the extract when kerosine is processed. These aromatics can be blended into gasoline. Their quantity depends on the boiling range of the raw feed stock to the extraction units. In order to recover valuable gasoline aromatics from the extract, the latter is caustic treated to remove the last traces of SO_2, and redistilled in the rerun unit shown in Figure 3.

In the rerun unit, the extract from kerosine treating is split into a light cut with an end point of 380-390 F. and a heavy cut boiling over 390 F. The light cut is one of the high octane component sof SACOR's premium grade gasoline, while the heavy aromatics are blended into diesel oil.

About 10-11 percent by weight of aromatics based on the kerosine are generally obtained. The clear F-1 octane number of the aromatic material is approximately 88-90. The addition of 1.5 cc TEL/US-gallon furnishes 93-95 octane number material.

SO_2 Extraction Plant Has Flexibility . . .

The SACOR plant is designed for the extraction of 600-700 tons/sd (4,900-5,700 bpsd) of Middle East kerosine distillates using about 100 Vol. percent SO_2 at 14 F. Data on the product quality, when handling Basrah kerosine are given in Table 1.

As an improvement of the smoke-point from 24 to final 45 is generally not necessary, SACOR treats its kerosine with only about 50 Vol. percent of SO_2. The Basrah raffinate then shows a smokepoint of 38-40, the yield of raffinate being about 80 percent by weight on raw feed. The maximum capacity of the Edeleanu plant will then be about 800 tons/sd (6,500 bpsd).

Straight-run gas-oil from Aramco crude has been treated with 100 Vol. percent SO_2 at 32 F. The capacity of the unit with this operation was then about 700 tons/sd (5,500 bpsd). The analysis of the feed, the raffinate and the extract are shown in Table 2. As seen in these data, the sulfur content of the gas-oil has been reduced to such an extent that SACOR meets the most stringent sulfur specifications for diesel fuels.

The daily capacity of the extraction plant when handling lube-oils is approximately 150 to 300 tons/sd (1,000 to 2,200 bpsd) using about 400-200 Vol. percent of SO_2.

The results obtained in the extraction of a U.S. heavy naphthenic lube-oil distillate are shown in Table 3. The improvement of the viscosity index from 9 to 58 with a yield of 74 percent is considered remarkable for this type of lube-oil. Data from other extraction operations indicate that the viscosity index can be improved still further by using higher extraction temperatures such as approximately 176 F. Extraction of lube-oils at high temperatures with liquid SO_2 as a selective solvent is therefore a most flexible and economical process in the production of lube-oils of high viscosity index.

The utility requirements for extracting 613 tons/sd of a Basrah kerosine using 100 Vol. percent of SO_2 at 14 F. are shown in Table 4.

Cooling water consumption is on the high side; during normal operation quantities are of the order of 3,500 to 4,000 gallons per ton of feed.

The SO_2 actually used up over long periods of time is less than 0.7 pounds per ton of kerosine.

TABLE 1—Extraction of Basrah Kerosine (100% by Volume SO_2 at 14 F)

	Products of Extraction Plant			Product from Rerun Unit	
	Feed	Raffinate	Extract	Caustic Treated-Light Aromatics	Caustic Treated-Heavy Aromatics
Properties					
Specific Gravity, 15C	0.789	0.768	0.865	0.835	0.900
ASTM IBP, F	315	315	320	305	400
ASTM EP, F	482	475	515	383	520
Flash Point, (P.M.) F.	.....	118	125	.....	187
Smoke Point, mm	24	45	.....	.....	.....
Sulphur wt. %	0.15	0.026	0.60	0.15	1.10
Aromatics Vol. %	.....	<2	76	69	82
SO_2 Content %	.....	0.01	0.02	.....	.....
F-1 Octanes (Clear)	.....	.....	.....	88	.....
F-1 Octanes (1,5cc TEL)	.....	.....	.....	93	.....
Throughput					
Tons/SD	613	460	153	73.5	79.5
Yield, wt. % on Feed	100	75	25	12	13

TABLE 2—Extraction of Aramco Gas Oil (100% by Volume SO_2 at 37 F)

	Feed	Raffinate	Extract
Properties			
Specific Gravity, 15C	0.845	0.815	0.963
ASTM IBP F	451	460	460
ASTM EP, F	684	703	> 752
Flash-Point, (P.M.) F	230	230	237
Sulphur, weight percent	1.05	0.19	4.08
Aromatics Volume percent	16	4	~ 80
SO_2—Content percent	.....	0.016	0.042
Throughput			
Tons/SD	600	462	138
Yield, weight percent on Feed	100	77	23

TABLE 3—Extraction of a Heavy Lubricating Oil Distillate (288% by Volume SO_2 at temp. gradient: + 122/100/77F)

	Feed	Raffinate	Extract
Properties			
Specific Gravity 104F	0.921	0.895	1.000
Viscosity, Engler, 122F	19.4	13.2	239
Viscosity Index	9.0	58.2	.....
Aniline Point, F	.....	212	.....
Flash Point, F	450	455	415
Pour-Point, F	20	.....	.....
Aromatics, Volume percent	.....	< 2	.....
SO_2—Content percent	.....	0.002	0.002
Yield, weight percent	100.0	74.1	25.9

TABLE 4—Utility Requirements for Treating
(Basis: 613 Tons Kerosine with 100% by Volume SO_2 at 14 F)

	Steam (115 psi), lbs.	Electric Power, Kwh	Cooling Water, Gallon
Per Day	255,000	3,863	3,120,000
Per Ton Kerosine	416	6,3	5,100

ACKNOWLEDGMENT

The authors wish to thank the S. A. Concessionária da Refinacao de Petróleos em Portugal for assistance in preparation of this manuscript. Their accumulation of data is sincerely appreciated.

Heat Transfer Nomographs

Part 8 – Heat transfer coefficients for liquids and gases outside tubes

Part 9 – Water film coefficients for normal and annular flow

Part 10 – Vapor condensation for saturated gases

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Monterrey, Mexico

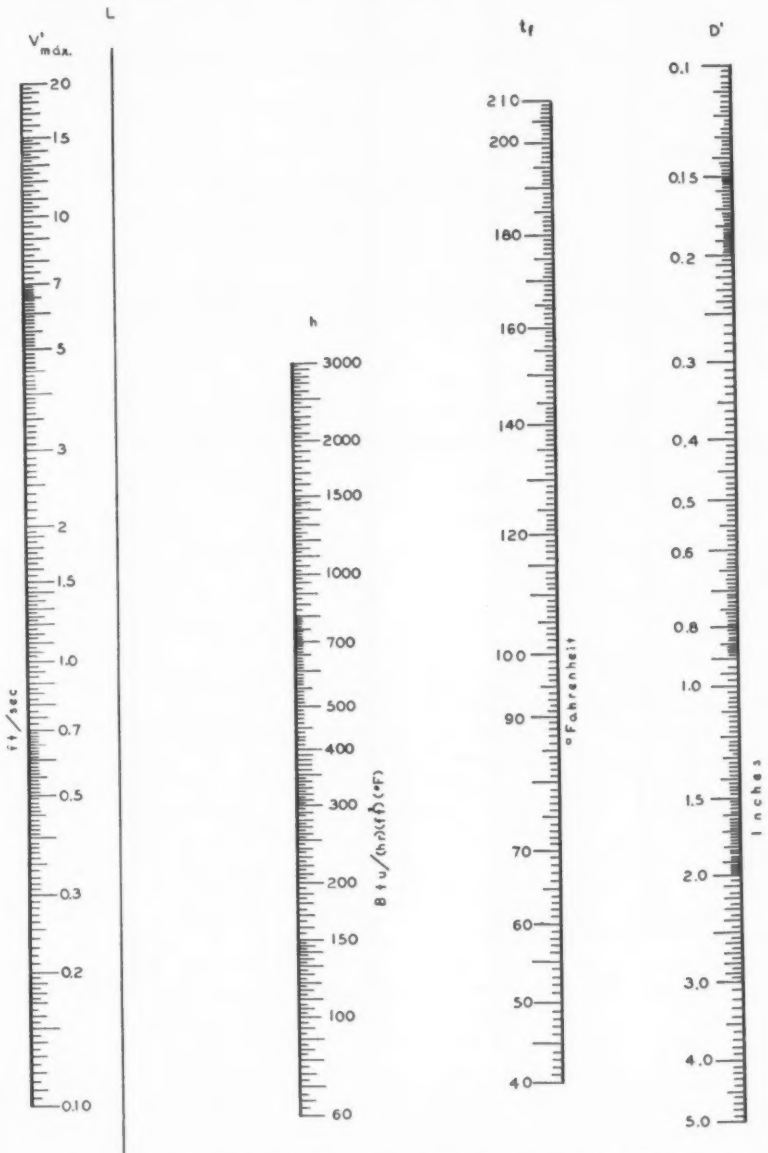

FIGURE 19—Film coefficients for water flowing normal through a bank of tubes.

WATER FILM coefficients involve detailed calculation. However, using these two nomographs, these film coefficients are readily found for water flowing normal through a bank of tubes or for annular flow conditions.

Water Flowing Normal Through Banks of Tubes. For water flowing perpendicularly to staggered bank of tubes, McAdams[14] recommends the following equation:

$$h_m = 370\,[1 + 0.0067\,t_f]\frac{(V'_{max})^{0.6}}{D'^{0.4}_o}$$

Where: h_m, Mean film coefficient, Btu/hr. sq. ft. F.
t_f, Film temperature, F.
V'_{max}, Maximum velocity based on cross section, ft./sec.
D'_o, External diameter of the tubes, inches

For tubes in line it is recommended to reduce the values of the film coefficient by 20 percent.

Example: Calculate the film coefficient for water at 100 F. flowing through a staggered bank of tubes, 1 inch external diameter with a velocity of 2 ft./sec.

Solution: Using Nomograph No. 19 a value of 930 Btu/hr. sq. ft. F. is found for the film coefficient.

Key : V'_{max} — t_f : L
L — D'_o : h

Film Coefficient in Anular Cross Sections. Wiegand[21] recommends the following equation for annular cross sections:

$$\frac{h\,D_e}{k} = 0.025\left(\frac{D_2}{D_1}\right)^{0.45} Re^{0.8}\,Pr^{0.4}$$

Where: D_1, External diameter of the internal tube, feet
D_2, Internal diameter of the external tube, feet
D_e, Hydraulic mean diameter, equal to $(D_2 - D_1)$

Example: Calculate the Nusselt number for an annular heat exchanger, with tubes 2 inches and 4 inches (I.P.S. 40), if Reynolds number is 10,000 and Prandtl number is 10.

Solution: Using Nomograph No. 20, the Nusselt number is found to be 138.

Key : Re — Pr : f_1
$D_2 - D_1$: f_2
$f_1 - f_2$: Nu

(See next page for Figure 20.)

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[14] McAdams, W. H., Heat Transmission, McGraw Hill Book Co., Inc., 1942.
[21] Wiegand, J. H., and Baker, F. M., Transfer Processes in Annuli, Transactions of American Institute of Chemical Engineers, Vol. 38, p. 569, 592 (1942).

TO BE CONTINUED

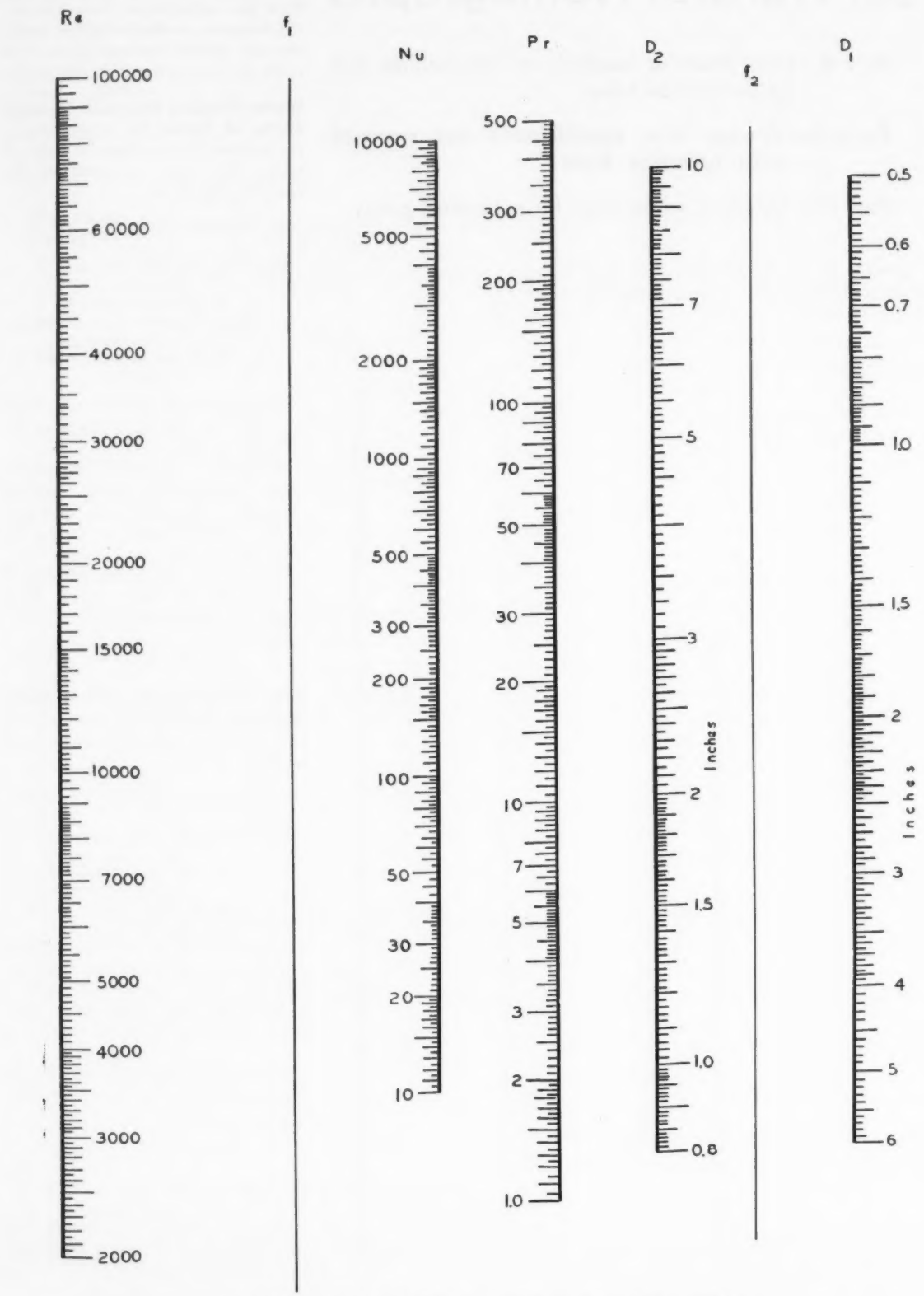

FIGURE 20—Film coefficients for water flowing in anular cross-sections.

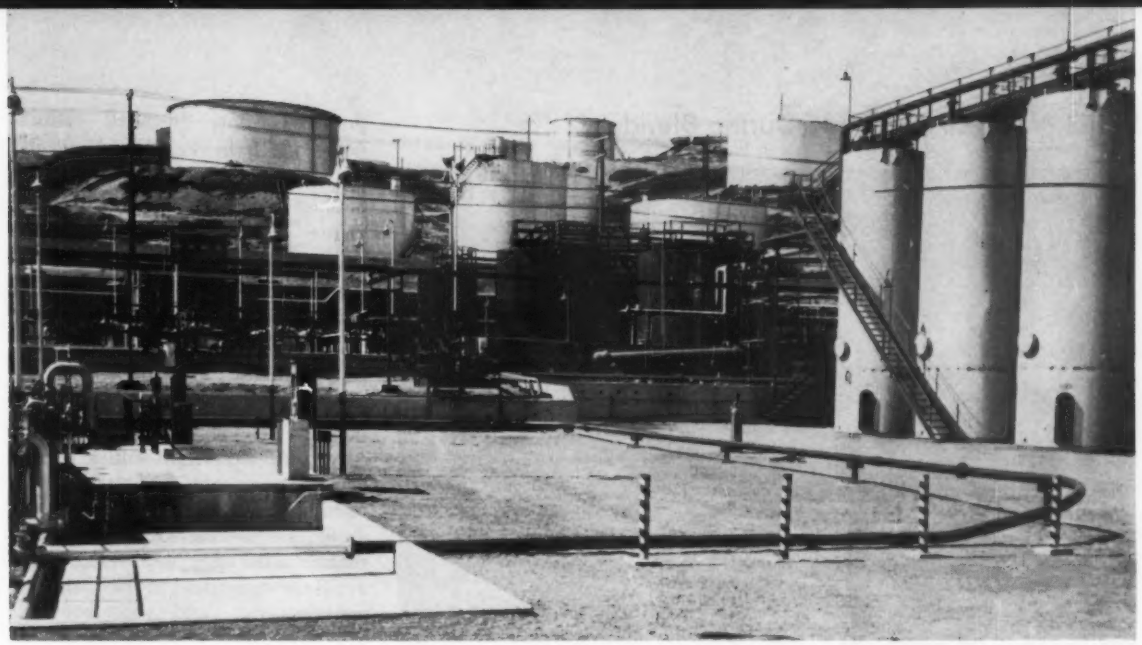

FIGURE 1—One-third of calibration loop run. Vacant slab area is for expansion of blender and pump station.

Try this method to . . .

Prove Meters ANY TIME During Blending

Using this system, you can switch from one component to another during the blend run and not interrupt the run

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Richmond, Calif.
G. H. Hervey
Bechtel Corporation, San Francisco

FOR IN-LINE gasoline blending, a meter proving system must operate without interrupting the blending operation. At the Standard Oil Company of California's Richmond refinery, the problem of conveniently and rapidly proving the accuracy of positive displacement meters was solved by an ingenious installation using a continuous calibration loop in which the pipeline pig is not removed from the loop except for occasional inspection. No conventional pig traps are provided and meters can be proven at any time without interrupting the metered flow. The loop has proven itself so practical that the Standard Oil Company of California is considering the installation of a similar system at an existing manifold equipped with ten meters. The original installation was designed by Bechtel Corporation engineers in cooperation with Standard Oil Company of California personnel.

The need for such a device arose from the installation of an in-line blending system for jet fuels. The blending system is an automatic in-line blender. It consists of individual component meters which provide the input to the blender. The various input signals are correlated by mechanical interconnections to provide a continuously accurate ratio of components. The actual control of the component flow is provided by conventional air-operated diaphragm valves.

The component meters are of the positive displacement type with individual output shafts mechanically connected to the blending panel. The necessary accuracy of the blend can only be maintained when the meters provide an accurate input into the blender mechanism. It is therefore necessary that the meters be proven for accuracy at regular intervals and correction factors established. A meter proving device became therefore an inherent part of the blending installation design.

What Was Needed. Established codes for meter proving were studied and the needs and desires of the operators of the blending system were considered during preliminary studies to set up criteria upon which

Prove Meters ANY TIME During Blending . . .

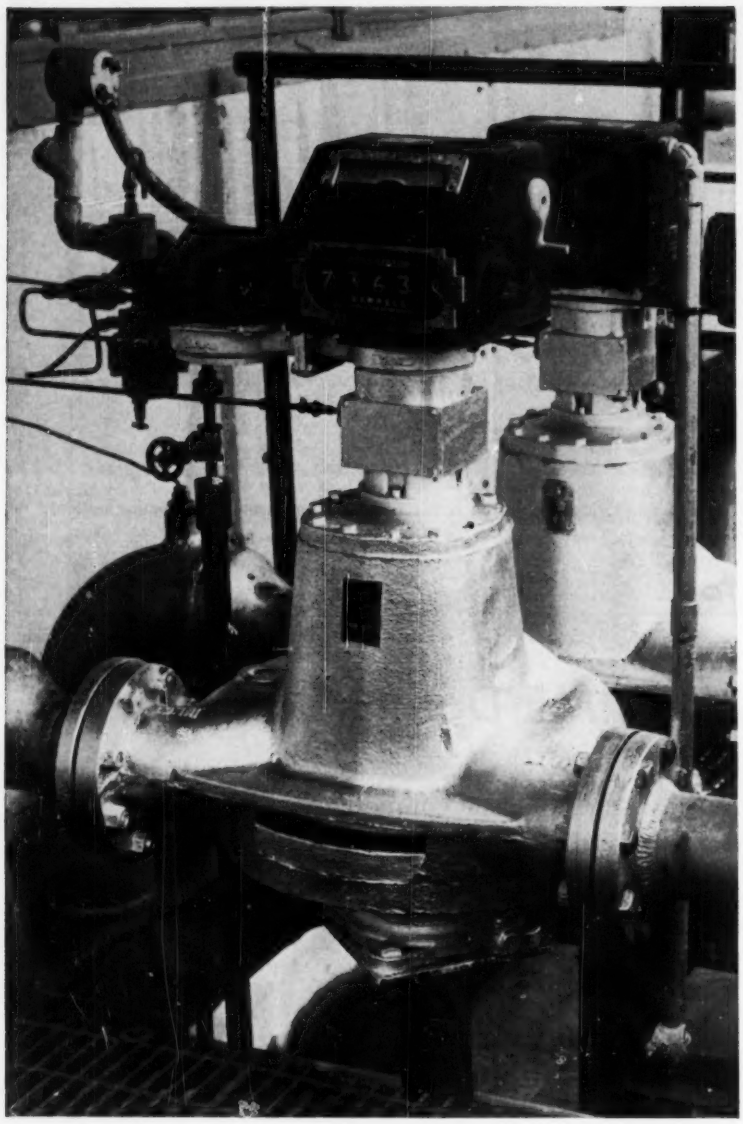


FIGURE 2—A calibration counter, shown left of main meter counter, is started when pig throws switch. Note instrument air line to clutch below calibration counter.

to base the meter proving design. Aside from the code requirements for accuracy, length of proving run, etc., the following special operator's requests were included in the design criteria:

- It must be possible to switch from proving one component meter to another during the blend run.
- The prover must operate during a blending run and without interrupting it.
- After a proving run has been started, it must stop automatically.
- Meter proving must be a one-man operation.
- The liquid which goes through the meter must also be used to prove it.

Why This Method Was Used. A survey was made of previously designed proving facilities. None were found to meet the design criteria set forth above. Prover tanks were undesirable because it is not practical to operate them during a blending run. Metering runs such as used on pipelines did not fit into the project layout. So-called calibration loops (in reality U-shaped metering runs) were rejected because it is necessary to manually move the pipeline pig from one end of the U to the other, a time consuming operation usually requiring more than one man. The possibility of reversing the direction of flow in such a U-shaped calibration run was rejected because it was felt that a pipeline pig for shuttling movement would present a serious maintenance and service problem. Further investigation showed that it should be possible to design a continuous calibration loop which would avoid the difficulties of the U-shaped metering run, and still meet all the requirements for accuracy and length of run.

Final Design. The design finally adopted provides for two component streams and meters with provisions for the addition of four more components. The principle of calibration is the one utilized in conventional pipeline meter proving runs in which a comparison is made between the meter reading and the actual quantity of fluid displaced through a calibrated length of pipe. For this purpose, switches are installed at the ends of the prover pipe. These switches operate clutches which connect the displacement meter mechanisms to special calibration counters. Means are provided to introduce a pipeline pig into the pipe through which it is pushed by the metered liquid with negligible slippage. In operation, the passage of the pipeline pig throws the start switch which engages the calibration counter on the meter (Figure 2). After having moved through the pipe, the pig contacts the stop switch which arrests the movement of the calibration counter. By comparing the calibration counter reading to the known calibration run volume, the accuracy of the meter and its correction factor are determined.

The design used in this installation disposes the calibration pipe run roughly in form of a rectangle (Figure 1). The two above mentioned switches are located along one side of this rectangle (Figure 3) and are separated by the operating valves and by a removable pipe section.

Details of the arrangement are shown in Figure 4. Because of the valve and piping arrangement, the pipeline pig does not have to be removed from the loop except for occasional inspection. Otherwise the pig can be moved from one station to the other and the calibration accomplished by setting valves only, as shown on the valve setting tabulation. No other operating labor is required.

Switching from one blend component to another can be accomplished without interrupting the blending flow. The finished blend in the line will be off test for approximately one minute while switching, until the loop has been purged of the previous component. The short-term, off-test condition is of such a small size that it will not throw a tank car or normal size tank truck load off test. The overall blend will be correct, providing that the same component is in the loop at the start and at completion of the blending run.

Removing The Pig. The pipeline pig must occasionally be removed from the line for inspection. For this purpose, the portion of the loop between the two main loop shutoff valves is equipped with a removable section (Figure 5). At the end of a calibration run, the pig stops in this section, which is connected to the

FIGURE 3—The pig trips this explosion-proof start switch.

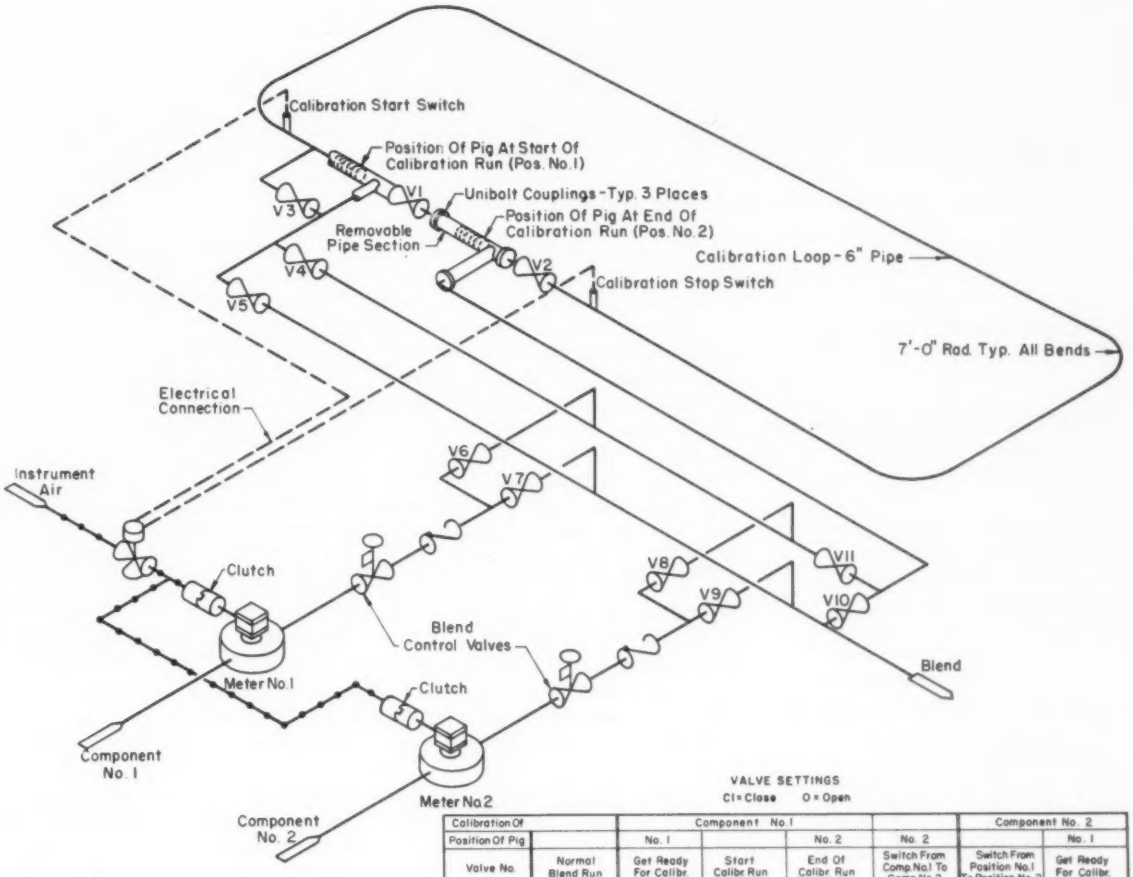


FIGURE 4—System diagram shows how either component can be run through test loop.

VALVE SETTINGS
Cl = Close O = Open

Calibration Of		Component No. 1						Component No. 2			
Position Of Pig		No. 1			No. 2		No. 2		No. 1		
Valve No.	Normal Blend Run	Get Ready For Calibr.		Start Calibr Run	End Of Calibr. Run		Switch From Comp. No.1 To Comp. No.2		Switch From Position No.1 To Position No.2		Get Ready For Calibr.	
		Sequence					Sequence		Sequence		Sequence	
V 1	Cl								O	1	Cl	7
V 2	O								Cl	3	O	2
V 3	O			Cl							O	1
V 4	O								Cl	6	O	3
V 5	Cl								O	2	Cl	6
V 6	Cl	O	2				Cl	2				
V 7	O	Cl	3				O	1				
V 8	Cl						O	3				
V 9	O						Cl	4				
V 10	Cl	O	1						Cl	5	O	4
V 11	Cl								O	4	Cl	5

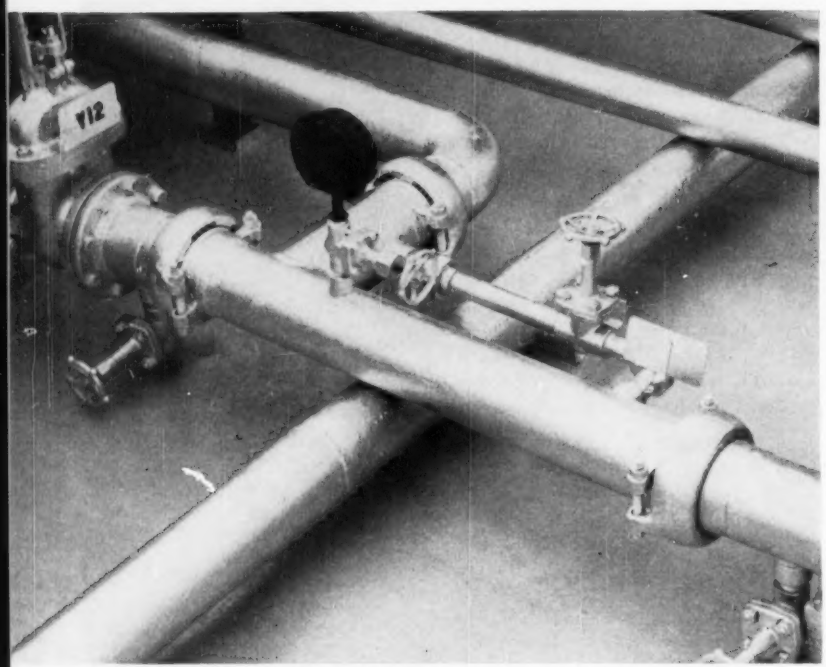
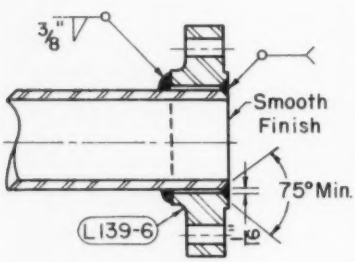
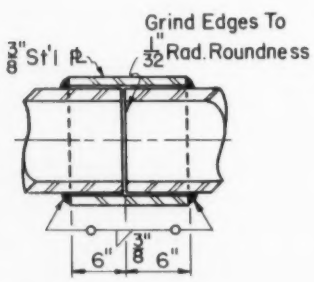


FIGURE 5—Removable section in test loop makes pig removal easy.



Typical Flange
On Calibration Line
No Scale
DETAIL A



Typical Piping Joint
In Calibration Line
No Scale
DETAIL B

FIGURE 6—Special pipe joints are so smooth that pig cups lasted 1½ years.

line by three pipe couplings of the Unibolt type. The part of the pipe system connected to the removable section is isolated by closing the appropriate valves and the pipe section drained and water washed through connections provided for the purpose. Then the removable section is uncoupled by removing three bolts and lowered to the concrete slab. The pig is then accessible for inspection and maintenance.

The loop provides for a run of approximately one minute for the largest meter. It consists of 6-inch pipe with full opening valves, 7-foot radius bends and special pipe joints shown in Figure 6. These pipe joints were developed to avoid any possibility of roughness due to weld penetration onto the interior surface of the pipe. They have proven their worth, as cups of the first pig used in the loop wasted over 1½ years with frequent use. Two years of use have proven the convenience and accuracy of this calibration loop.

Meter Strainers. Another important feature is incorporated into this installation. The positive displacement meters are protected by strainers of unusually high quality. The light component stream is equipped with a dual basket strainer with 200-mesh baskets. The heavier component stream goes through a micronic sintered bronze filter paralleled by a 100-mesh basket strainer, permitting operation while the filter is being backwashed or chemically cleaned. These units have been known to plug up occasionally on extended runs and shut down the blender; but the shutdowns do not last long, due to the above mentioned standby features. No displacement meter repairs have been needed in two years of operation and the meters have remained close to their original accuracy. # #

About the Authors

Ranney Hervey

R. P. Ranney is a senior engineer with Standard Oil Co. of Calif., Richmond, Calif. Holder of an A.B. degree from Stanford University and a B.S. degree in mechanical engineering from the University of California, he is a registered professional engineer. Ranney has been with Standard since 1944, when he joined the Engineering division as a design engineer in maintenance and construction at the Richmond refinery.

G. H. Hervey is a senior engineer with Bechtel Corp., San Francisco. He received his advanced degree (equivalent to M.S.) in mechanical engineering from Ecole Federale Polytechnique, Zurich, Switzerland, and is a registered professional engineer in California. Before joining Bechtel in 1954, he was with Kaiser Engineers, San Francisco. With Bechtel, he has supervised mechanical design and instrumentation on Refinery division projects, and construction of refinery improvement projects.

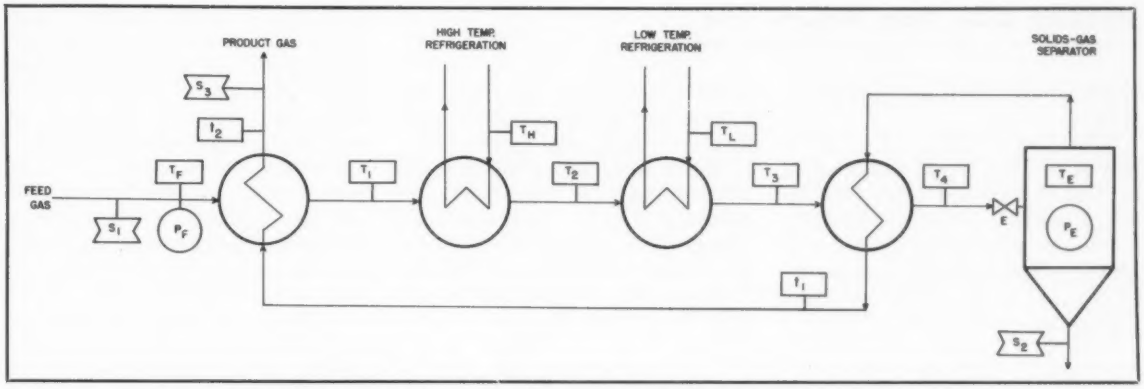


FIGURE 1—Schematic diagram for the removal of CO_2 from natural gas by freezing.

A new process . . .

Freezing CO_2 from Natural Gas

W. E. Clark and F. Kurata
University of Kansas
Lawrence, Kansas

THIS ARTICLE introduces a different method for removing carbon dioxide. This method, the freezing out of the carbon dioxide, may be more economical in many cases. Only a preliminary investigation has been made, but that is sufficient to indicate that the freezing method has promise.

According to the data published by Donnelly and Katz for the carbon dioxide-methane binary,[1] carbon dioxide can separate from methane as an almost pure solid phase at low temperatures. Therefore, unless other constituents interfere, a simple solids-gas separator, such as a cyclone, can be used to remove carbon dioxide from natural gas. The method is shown schematically in Figure 1.

The temperature, T_E, and the pressure P_E, in the solids-gas separator are set by the natural gas purity desired. In Figure 2, the required temperature and pressure have been plotted as functions of the product purity.

Figure 2 was developed in the following manner. At pressures below 700 psia carbon dioxide separates from the vapor phase as an almost pure solid over a limited temperature range. The upper temperature limit is that at which solid carbon dioxide first begins to form. The amount of solid carbon dioxide increases as the temperature is lowered; and the methane purity in the

TABLE I—Calculated Values for Figure 1

Mole Percent CO_2 in Feed	T_F °F	P_F psia	T_1 °F	T_2 °F	T_3 °F	T_4 °F	T_E °F	P_E psia	t_1 °F	t_2 °F	S_1 Million SCFD	S_2 Million lb./day	S_3 Million SCFD	Refrigeration Horsepower: High Temp.	Low Temp.	Total
5	90	1500	—40	—40*	—40*	—40*	—168	250	—168*	54	CH_4:98 CO_2:5.2	0.37	CH_4:98 CO_2:2	0	0	0
10	90	1500	66	58	58**	—57	—168	250	48	80	CH_4:98 CO_2:10.9	1.03	CH_4:98 CO_2:2	300	0	300
20	90	1500	31	—10	—32	—82	—168	250	— 42	80	CH_4:98 CO_2:24.5	2.61	CH_4:98 CO_2:2	3000	600	3600
30	90	1500	26	—10	—75	—107	—168	250	— 85	80	CH_4:98 CO_2:42	4.64	CH_4:98 CO_2:2	7000	3000	10000

Based on production of 100,000,000 scfd of product gas containing 98 mole percent methane and 2 mole percent carbon dioxide.
T_H = —20 F
T_L = —85 F
No allowance has been made for heat leakage in heat balances.
Five percent has been added to refrigeration loads to account for heat leakage, and a compressor efficiency of 75 percent has been assumed.
* No refrigeration and only first heat exchanger required.
** No low temperature refrigeration required.

vapor phase increases correspondingly.

The lower temperature limit is that at which a liquid phase begins to form. This liquid phase contains a high percentage of methane. Thus, the lower temperature limit corresponds to maximum methane purity without loss of yield. Since the lower temperature limit occurs when a liquid phase joins the vapor and solid phases, this lower temperature limit is a three-phase locus.

Operation in which liquid methane is formed after expansion is also possible. In this case the liquid methane may be separated from the solid and heat exchanged with the feed gas. This case was not investigated here. Thus, Figure 2 is a plot of temperature and pressure versus vapor phase composition for the low temperature end of the three-phase locus. The data of Donnelly and Katz[1] and of Kohn and Kurata[2] were used in developing this plot.

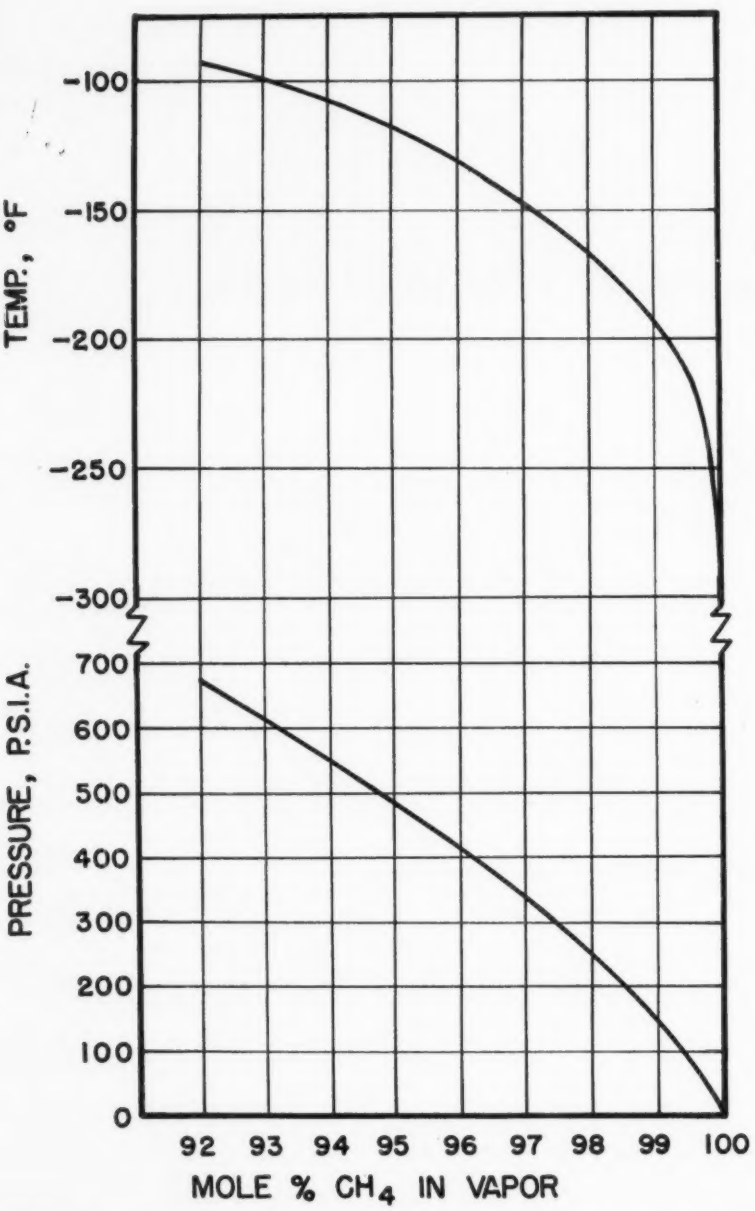


FIGURE 2—Temperature and pressure in the solids-gas separator vs. vapor phase composition.

In order to gain some idea of the advantages and disadvantages of this new method for removing carbon dioxide from natural gas, some calculations have been made on mixtures of methane and carbon dioxide. These were based on feed gas compositions of 30,20,10, and 5 mole percent carbon dioxide, and on production of 100,000,000 SCFD of natural gas containing 98 mole percent methane and 2 percent carbon dioxide. According to Figure 2, the temperature in the solids-gas separator must be —168 F. and the pressure 250 psia in order to achieve this purity.

The field gas was assumed to arrive at a temperature of 90 F. and a pressure of 1500 psia. In passing through the heat exchangers of Figure 1, a 10 F. approach and negligible pressure drop were assumed. So the field gas arived at the expansion valve, E, at some temperature T_4 and a pressure of 1,500 psia. At the valve it passed through a Joule-Thomson expansion to the required temperature of —168 F. and pressure of 250 psia; and the excess carbon dioxide was frozen out.

The greater the amount of carbon dioxide in the field gas, the lower the temperature T_4 must be in order to freeze out the carbon dioxide. This places a limit on the carbon dioxide percentage which can be handled in this system. This limit is about 30 mole percent carbon dioxide. At higher percentages of carbon dioxide a solid phase, which will plug the heat exchangers, forms before the low temperature required for T_4 can be achieved.

If the field gas contains more than 30 mole percent carbon dioxide, product gas can be recycled to reduce the carbon dioxide in the feed to 30 percent or less. If the field gas contains constituents other than methane and carbon dioxide, the freezing point may be depressed sufficiently so that much higher concentrations of carbon dioxide can be handled. However, this aspect has not been investigated further.

If the solid carbon dioxide, as well as the product gas, could be used in a heat exchanger to cool the

feed stream, probably no refrigeration would be required. Under the conditions considered, the enthalpies of the gases are greater at low pressures than at high. Therefore, neglecting any heat of mixing, the methane and carbon dioxide could be withdrawn from the system at temperatures below the feed temperature while maintaining a heat balance.

However, problems can be anticipated in the use of dry ice for cooling on this large a scale. Therefore, the calculations have been made with the dry ice withdrawn from the system. As shown by Figure 3, the refrigeration load depends upon the amount of carbon dioxide to be frozen out.

In calculating the refrigeration load, ammonia was used as the high temperature refrigerant and ethane as the low temperature. An evaporator temperature of $T_H = -20$ F. was assigned to the ammonia system; and an evaporator temperature of $T_L = -85$ F. was assigned to the ethane system.

Cooling water at 90 F. was used in each refrigeration system condenser to cool the refrigerant to 100 F.; and the ethane was further cooled to —10 F. by heat exchange with the ammonia evaporator.

The heat balances indicated by Table 1 were determined assuming no heat leakage into the system and negligible heat of mixing for methane and carbon dioxide. Five percent of the calculated refrigeration load was added to both the high temperature and the low temperature refrigeration loads to account for heat leakage into the system. The theoretical horsepower requirements for the refrigeration compressors were determined; and an efficiency of 75 percent was used to calculate the horsepower requirements shown in Table 1. No attempt was made to find the minimum horsepower, and the results of Figure 3 and Table 1 are merely indicative.

For a field gas of high pressure and low carbon dioxide content, removal by freezing seems worth further study. The equipment is simple and little or no refrigeration is required. For higher carbon dioxide contents the refrigeration load becomes great, and either the dry ice must have value or some method of using it to cool the feed stream must be developed. For carbon dioxide content above about 30 mole percent some product gas probably would have to be recycled to prevent a freeze-up in the precoolers.

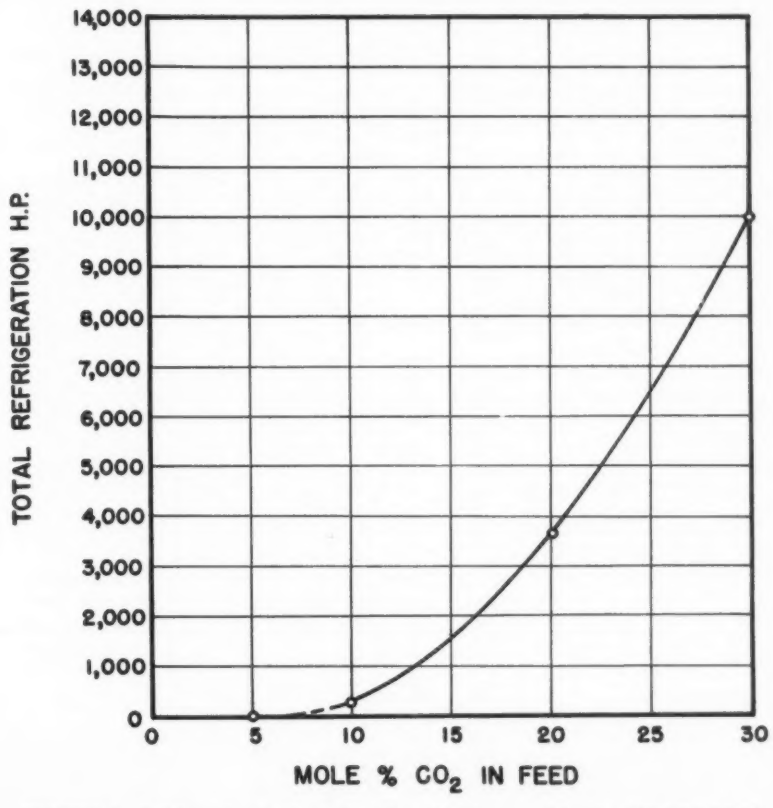


FIGURE 3—Refrigeration load as a function of feed composition for 100 MM SCFD product containing 2 mole percent CO_2.

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About the Authors

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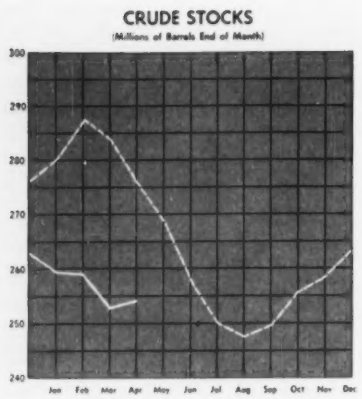
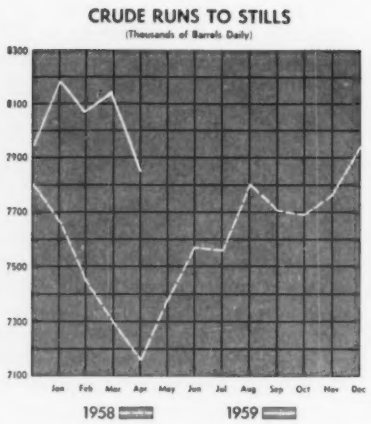
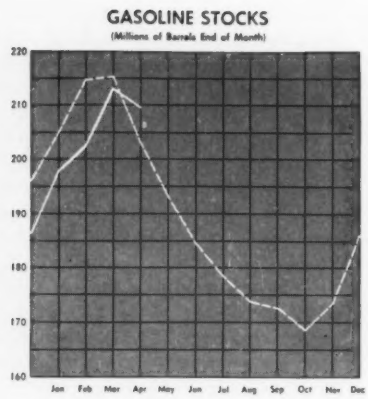
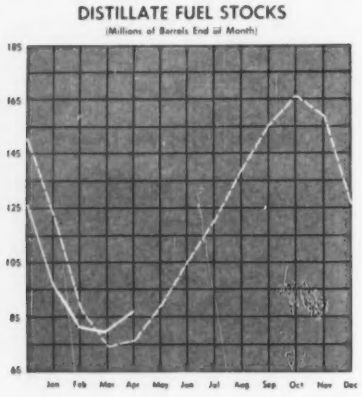
Dr. W. E. Clark is a professor of chemical engineering at the University of Kansas, where he is in teaching, research and consulting. He has a B.S. degree from Case Institute of Technology and M.S. and Ph.D. degrees from the University of Michigan. For 11 years Dr. Clark has been doing research and consulting work in low temperature phase and volumetric behavior. Before that he was a research associate at Michigan's Engineering Research Institute; plant engineer, Plasteel Products Co., and chemical engineer, Atlas Powder Company.

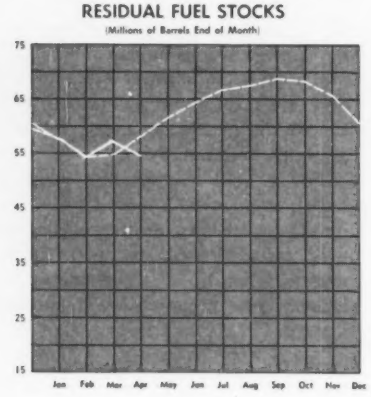
Dr. F. Kurata is an instructor at the University of Kansas, where he is also working toward a Ph.D. degree in chemical engineering. He received a B.S. degree in chemical engineering from the University of Marquette and a B.S. degree in physics from the University of Chicago. Dr. Kurata was a process engineer for Socony Mobil Oil Co. from 1950-53 and a chemical engineer for Midwest Research Institute, from 1953-58.

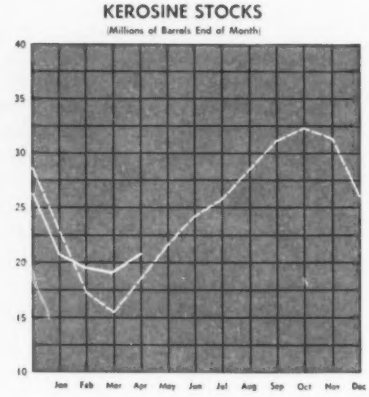












Taking Stock

- Crude stocks starting to climb
- Runs to stills down sharply
- Residual stocks drop off

U.S. Petroleum Demand and Supply (Thous. Bbls. Daily)

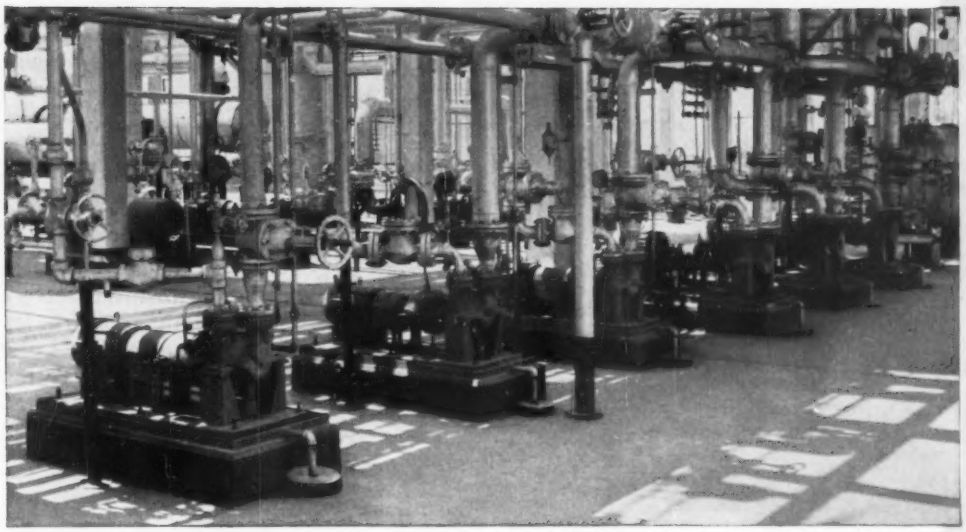
ITEM	April 1959	April 1958	April % Diff.	Mar. 1959	January-April 1959	January-April 1958	January-April % Diff.
DEMAND							
All Oils, Total Demand	9,092	8,857	+ 2.7	9,901	10,212	9,684	+ 5.5
Domestic Demand	8,857	8,588	+ 3.1	9,631	9,960	9,420	+ 5.7
Export Demand	235	269	—12.6	270	252	264	— 4.6
Gasoline, Total Demand	4,076	4,033	+ 1.1	3,913	3,844	3,655	+ 5.2
Distillate, Total Demand	1,660	1,580	+ 5.1	2,201	2,412	2,341	+ 3.0
Kerosine, Total Demand	188	205	— 8.3	342	395	428	— 7.7
Residual, Total Demand	1,511	1,435	+ 5.3	1,803	1,893	1,685	+12.3
CHANGE IN STOCKS							
All Oils, Change in Stocks	+223	—178	.....	+203	—244	—660	.....
NEW SUPPLY							
Total New Supply	9,315	8,679	+ 7.3	10,104	10,006	9,025	+10.9
Domestic Production, Total	7,991	7,057	+13.2	8,023	8,047	7,353	+ 9.4
Crude Oil	7,126	6,288	+13.3	7,173	7,179	6,555	+ 9.5
Natural Gas Liquids	865	769	+12.5	850	868	798	+ 8.8
Imports, Total	1,324	1,622	—18.4	2,081	1,959	1,672	+17.2
Refined Products	565	761	—25.8	1,193	1,055	737	+43.1
Crude Oil, Total	759	861	—11.9	888	904	935	— 3.3
Crude, East Coast	579	721	—19.7	696	711	783	— 9.2
CRUDE RUNS							
Crude Runs to Stills	7,863	7,189	+ 9.4	8,149	8,093	7,435	+ 8.9
Domestic Crude	6,933	6,330	+ 9.5	7,209	7,145	6,524	+ 9.5
Foreign Crude	930	859	+ 8.3	940	948	911	+ 4.1

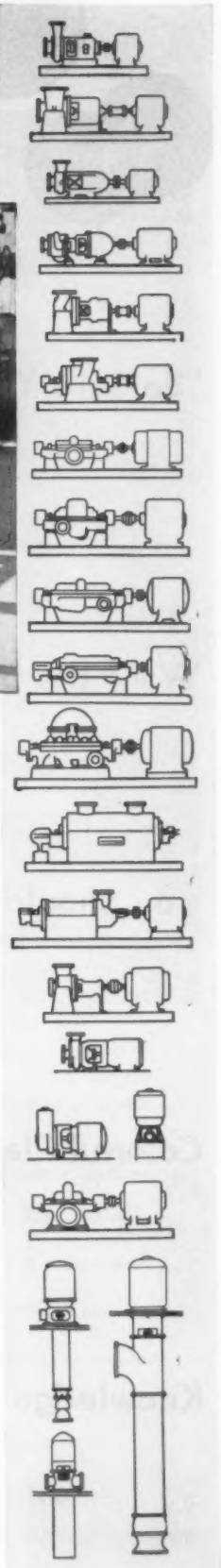
U.S. Stocks of Oils (Million Bbls. at End of Month)

KIND OF OIL	TOTAL IN U.S. Apr. 1959	TOTAL IN U.S. Apr. 1958	TOTAL IN U.S. % Diff.	TOTAL IN U.S. Mar. 1959	EAST OF CALIFORNIA Apr. 1959	EAST OF CALIFORNIA Apr. 1958	EAST OF CALIFORNIA % Diff.	EAST OF CALIFORNIA Mar. 1959
All Oils	759.5	762.1	— 0.3	752.8	.....	.....	.....	.....
Crude Oil	254.2	274.0	— 7.2	253.5	216.2	230.4	— 6.2	214.0
Gasoline	209.6	206.3	+ 1.6	213.3	180.1	178.1	+ 1.1	184.0
Distillate Fuel Oil	85.6	76.2	+12.3	78.1	74.7	64.7	+15.5	64.9
Kerosine	21.1	18.7	+12.8	18.4	20.6	18.3	+12.6	18.2
Residual Fuel Oil	54.5	58.0	— 6.0	57.9	27.5	26.8	+ 2.6	30.0

Sources for above 2 tables: U.S. Bureau of Mines monthly reports, except last 2 months based on API and Bureau of Mines weekly reports and PETROLEUM REFINER estimates.

HOW TO PICK A WINNER IN THE "OCTANE RACE"





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Valuable Reading Ahead

Here's a quick run-down on what's presented in this month's non-technical sections. These departments will keep you right up-to-date with what's new and different in this rapidly changing oil industry.

"Be Sure You Write What You Mean"

That's pretty good advice, but sometimes it's difficult to follow. Maybe you know exactly what you want to say but just can't seem to get the correct message down on paper. On the other hand, perhaps your writing is sometimes misinterpreted or ignored. In either case you have a communications problem. This month's lead story in "As Management Sees It" will help you with such a problem, as it gives some valuable pointers on how to improve your letter and report writing. To read "Be Sure You Write What You Mean," just . . .

Keep Going to Page 287

Want the Best?

As a man interested in doing what's most economically feasible to keep your plant modern and in top shape, you need to know the latest in equipment developments. The monthly Refiner feature, "New Equipment and Literature," will give you a quick rundown on the latest and best implements for your plant. To learn more . . .

Keep Going to Page 358

You Should Know

"Suppliers Notes" is a department full of information you need to know about the companies and men that supply the oil, gas and petrochemical processing industry. This handy guide will help you keep up with the people who serve your plant, and any extension of facilities which will be of service to you. To see for yourself . . .

Keep Going to Page 340

Colorful Plant

Superior Oil Co. has applied a touch of "eye-appeal" to its new plant in Cameron Parish, La. The gas processing plant is insulated with colored enameled aluminum. To learn the "whys" and "hows" of this unusual unit you'll want to read this month's "Who's Building" department. It's full of information on your industry's construction progress. Simply . . .

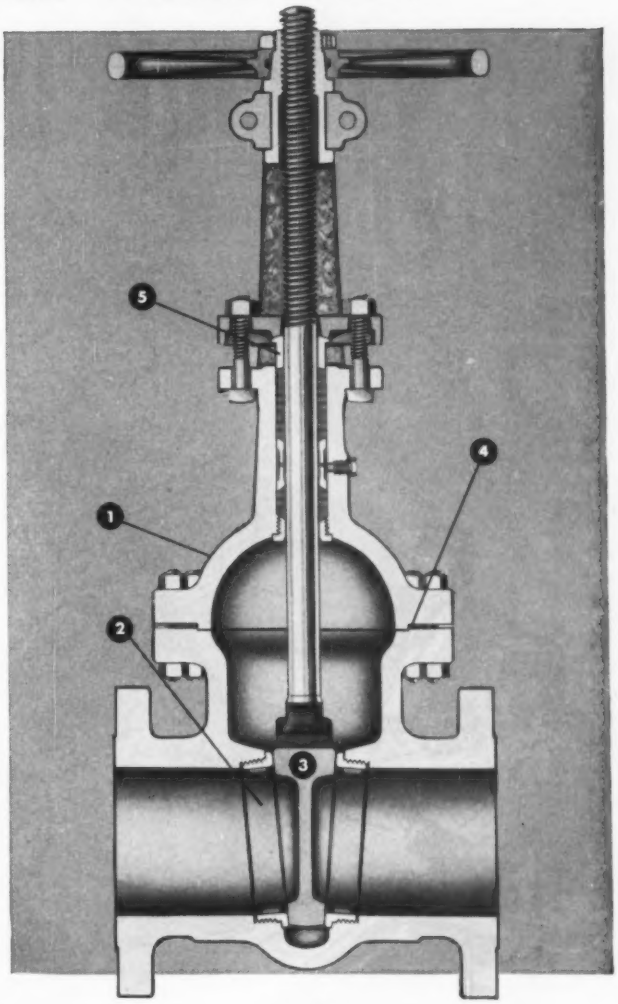
Keep Going to Page 268

Knowledge is the Key

Knowledge is the key to success, at least one of them. And, what better way is there to gain the knowledge you need to advance than by reading a good book or report on a subject important in your industry. If you would like to learn about some of the better publications hot off the press . . .

Keep Going to Page 326

Crane quality in 300-pound steel gates is no secret... just an "INSIDE STORY"



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3. Disc and stem made of Exelloy*.

   *Crane Exelloy (12% chromium) in body seat rings, disc and stem is your assurance of maximum wear-resistance and strength. Crane valves with Exelloy trim last longer, need minimum maintenance and postpone replacement far longer than valves which do not have Exelloy protection.
4. Self-centering, male and female bolted, gasketed bonnet joint assures a strong, tight seal.
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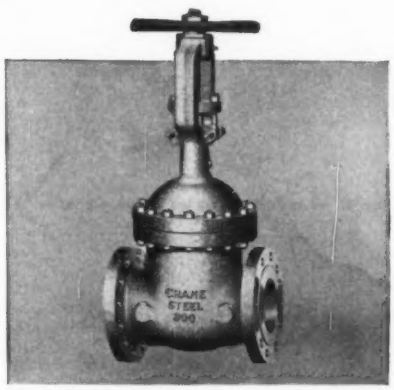

Crane 33X, 300-pound, flanged end, cast steel gate valve.

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"Crane 33X, 18-inch gates—*end long-standing leakage problem*—now in service 3 years without leaks, and no maintenance whatever." *Southwestern butadiene plant.*†

"Crane 33X, 6-inch gates *handle 800° F. oil 4 years* without leaking—still close tightly, easily." *Oklahoma refinery.*†

"Crane 33X, 8-inch gates *control 600° F. oil on crude oil* unit 8 years without maintenance." *Ponca City refinery.*†

"Crane 33X, 6-inch gates *still seat tightly; operate smoothly after 11 years on 750° F. line to pump for tar stripper bottoms.*" *Southwest refinery.*†

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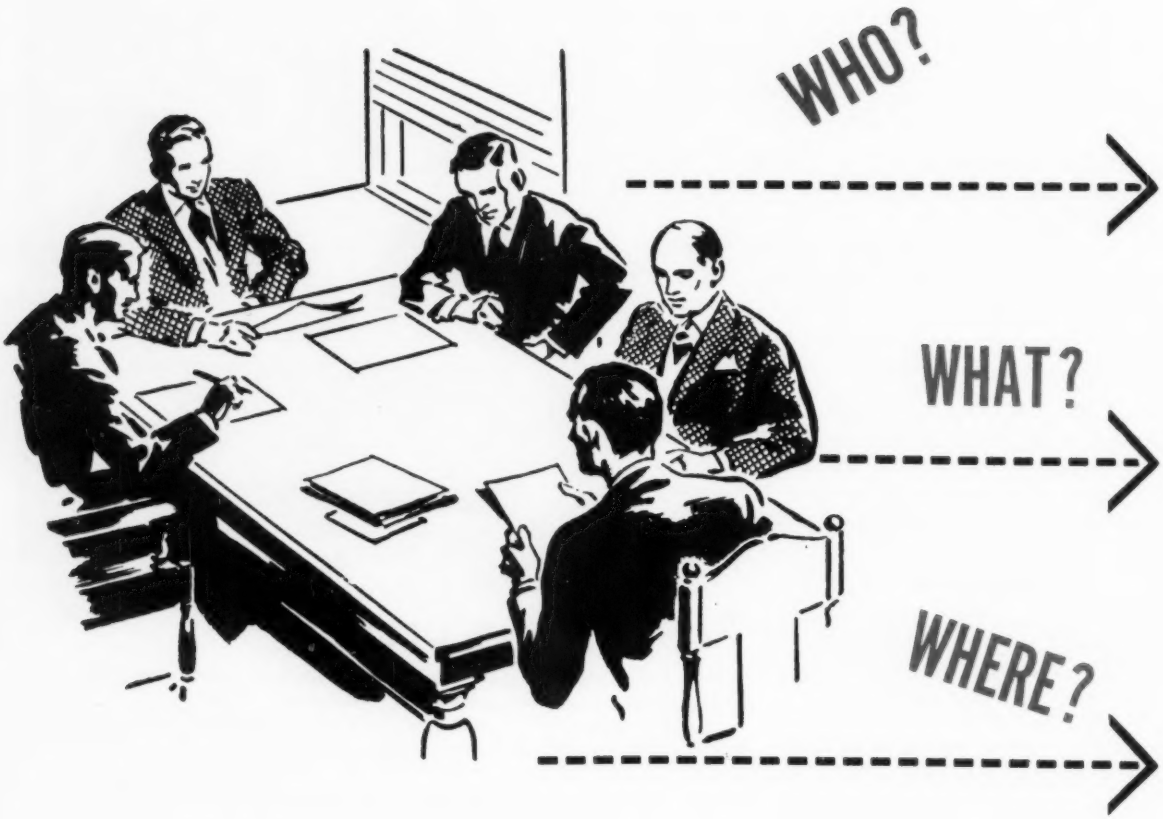

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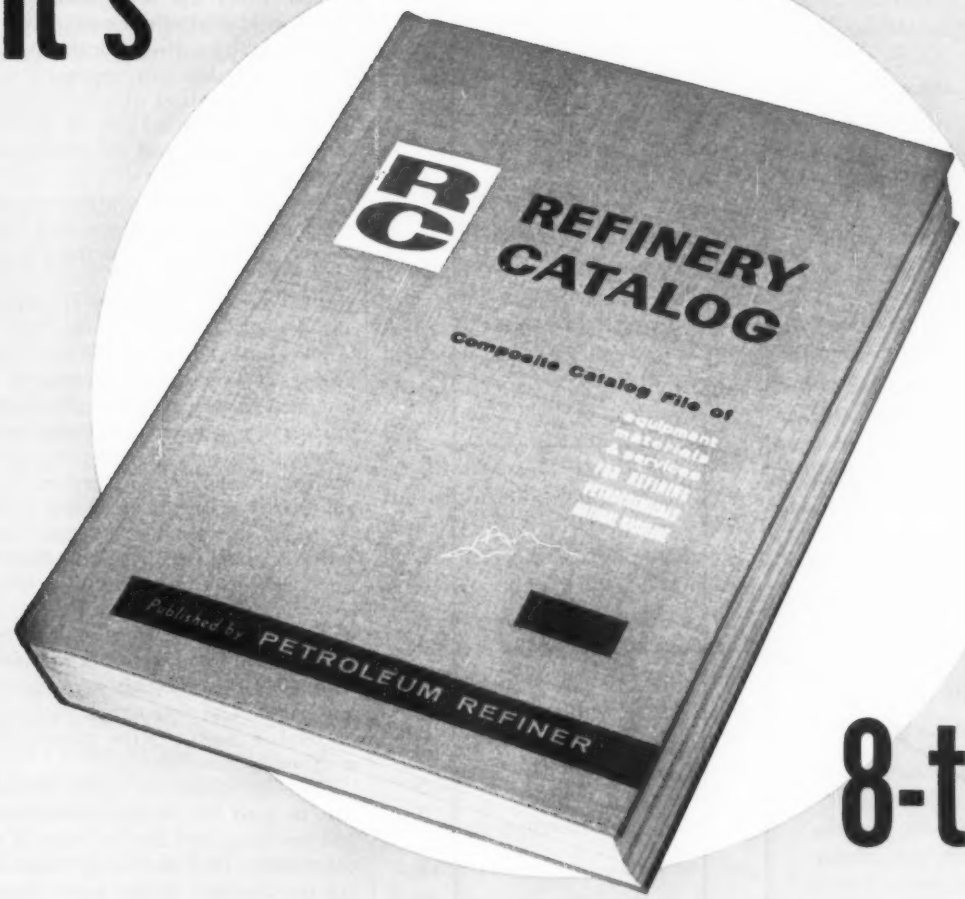

8-to-1

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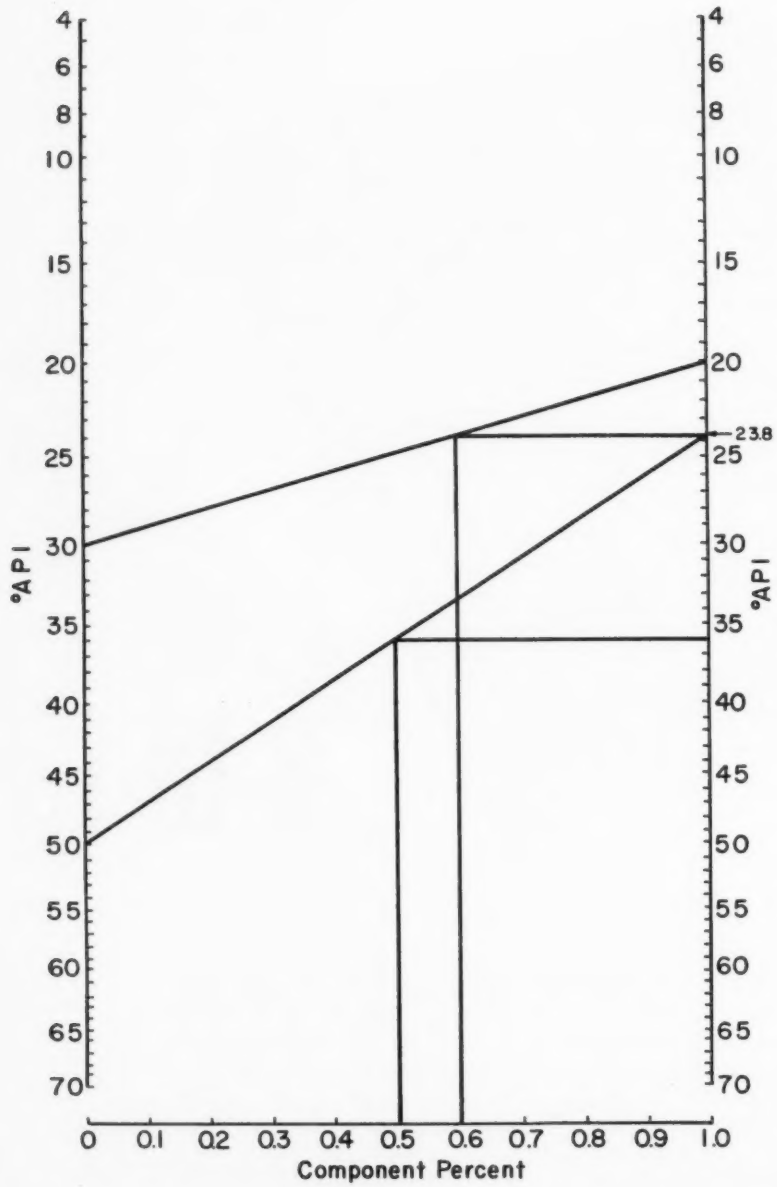
How to Do It...

Short Cut to API Gravity of Blends

This handy nomograph, based on an elementary geometrical principle, can save you time



In the "How To Do It" Section of the December, 1958 issue of PETROLEUM REFINER, a nomograph for use in determining the gravities of blends of hydrocarbon fractions was published.

One reader has been working on the same idea after encountering a number of blending calculations in recent work. His first approach was purely mathematical with the solution involving determination of a large number of points and the plotting of a series of curves.

He finally arrived at a very simple solution based on an elementary geometrical principle. It has the advantage that it is easy and fast to use and can be constructed by anyone to any desired scale.

The chart shows two identical vertical gravity scales separated by a length. The gravity scales are linear in *specific gravity* but are labeled with volume fraction scale of convenient equivalent values of API degrees. For any two components of known gravity which are assumed to blend linearly, a straight line drawn between the gravity axes represents all possible resultant blend gravities. The intersection of the gravity line with a vertical drawn from the composition scale gives the resultant gravity for any blend. The nomograph may also be used in a step-wise manner for multi-component blends.

For convenience, the left-hand scale may be used for the light component and the right-hand for the heavy. The composition scale is then in terms of volume fraction of the heavy component.

Examples of the use of the nomograph are as follows:

• Find the resultant gravity of a blend of 60 volume percent of a 20 degree API oil and 40 volume percent of a 30 degree API oil. Connect 30 on the left-hand scale with 20 on the right-hand scale by a straight line. Find the intersection of a vertical

IT'S NEWS! IT'S NI-O-NEL!

...a field-proven Inco Nickel Alloy for handling certain hot acids and oxidizing chemicals

Inco is now making available a field-proven alloy to handle corrosive conditions of unusual severity.

The alloy, called Ni-o-nel*, is made of Nickel (42%), chromium (21.5%), and iron (30%) with additions of molybdenum and copper. It is highly resistant to hot sulfuric, sulfurous and phosphoric acid conditions and to oxidizing conditions such as nitric acid solutions, nitrates and cupric, ferric and mercuric salts, except the chlorides.

Ni-o-nel alloy is stabilized by the addition of titanium and by its moderately low carbon content to prevent attack due to carbide precipitation.

In phosphoric acid:

1. Ni-o-nel alloy submerged cylinders and baffle plates in submerged combustion evaporators concentrating wet process phosphoric acid at temperatures up to 280°F, are giving 3 to 5 times the service life of previously-used materials.

2. In the dip pipes of units concentrating phosphoric acid by passing preheated air into the acid, Ni-o-nel alloy outlasted the previous alloy by 11 to 7.

3. In a defluorinating unit handling phosphoric acid of 54% P_2O_5 content, Ni-o-nel alloy lasted 2 to 6 times longer than the best previously-used alloy.

4. Ni-o-nel alloy can also be used in many similar applications such as hydrocarbon polymerization processes using phosphoric acid as catalyst, and for heating coils in the application of phosphate coatings to steel.

In sulfuric acid:

1. Platecoils of Ni-o-nel alloy have been used for heating a 12% (by wt.) sulfuric acid pickling bath maintained at 170°F. The platecoils lasted approximately 3 years (6 times longer than those of another resistant alloy).

2. Ni-o-nel alloy dancer roll arms in a continuous pickler used for processing steel strip in 8-12% sulfuric acid at 130°F temperature have so far lasted 17 months – 3 times longer than the previously-used alloy, and are still going strong. The Ni-o-nel alloy parts are subjected to considerable aeration as well as to the pickling solution itself.

In other corrosives:

1. Sulfurous acid. Ni-o-nel alloy has been shown to be superior to alloys customarily used to handle sulfurous acid in pulp and paper applications and in handling sulfurous combustion gases.

2. Nitric acid mixtures. Ni-o-nel alloy is resistant to nitric acid solutions of practically all temperatures and concentrations and shows good promise for handling such mixtures as nitric-sulfuric, nitric-phosphoric and some nitric-hydrofluoric acid solutions.

3. Organic acids. The alloy is resistant to most organic acids and has excellent resistance to boiling concentrated acetic acid, acetic-formic mixtures, maleic and phthalic acid and a number of others.

4. Sea water and chlorides. This alloy not only resists a wide range of chemical corrosives but also certain troublesome salt cooling waters, making it particularly adaptable for heat exchanger equipment. It resists pitting in salt water and has excellent resistance to stress-corrosion cracking.

*Registered trademark

Ni-o-nel alloy is a fully developed engineering material

Ni-o-nel alloy is made in all mill forms needed for fabricating process equipment... including welding electrodes. To get detailed information on this new engineering material, write for Inco's booklet, "Introduction to Ni-o-nel."

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N.Y.

INCO NICKEL ALLOYS

For more data on advertised products, use Readers' Service Cards, last page.

"give me ONE good reason"

That's what the man said, "Give me one good reason for buying a Platinum Reforming Catalyst from you. One brand's pretty much like another." And so it would seem on the surface. We could argue with conviction that Houdry 3-G often produces very high octane reformates at a lower cost and that the rate of catalyst deactivation between regenerations is very low. But even if Houdry 3-G were exactly like all others, there is one important reason why Houdry should be your source of supply:

To our people catalysis is a way of life. We not only develop and make catalysts but we understand how they work from engineering to operation. If you want a Platinum Reforming Catalyst with a pedigree as long as your arm, pick up your phone and call us.

* HOUDRY CATALYSTS

HOUDRY PROCESS CORPORATION
1528 Walnut Street, Philadelphia 2, Pa.

*Houdry means Progress . . . through Catalysis

How To Do It . . .

drawn from the 0.6 point on the composition scale with the gravity line. The result, read on either the left or right-hand scale, is 23.8 degrees API. This is identical with the calculated result.

• What is the resultant gravity of a blend of the following oils:

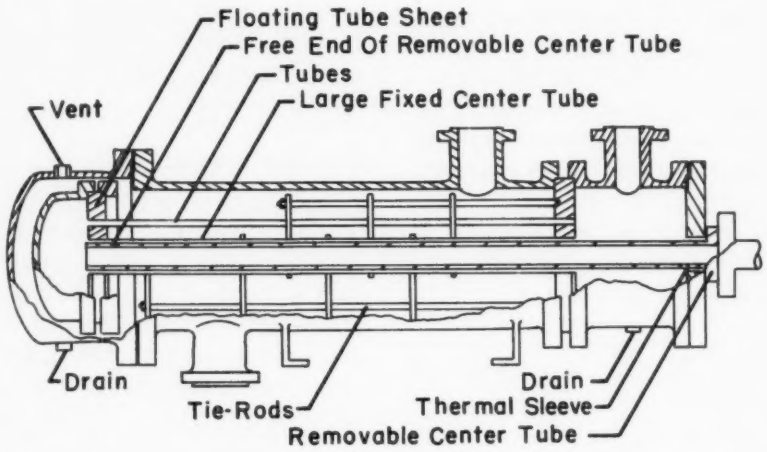
• 30 volume percent at 20 degrees API?

• 20 volume percent at 30 degrees API?

• 50 volume percent at 50 degrees API?

Considering a blend of the two heavier components only, the 20 degree API oil constitutes 0.6 volume fraction of the blend. The resultant gravity for the two heavy components is determined as in Example 1. The result, 23.8, is now connected with the value, 50, on the left-hand scale. The final result is 36 degrees API, read at the intersection of the new gravity line and a vertical from the 50 percent point on the composition scale (the two heavy oils constitute 50 volume percent of the total blend). This graphical result is identical with the calculated value.

This idea was submitted by Bernard Kouzel, Garden Grove, Cal.



Exchanger Handles a Wide Heat Range

Standard floating head heat exchangers are generally built with one shell pass and two or more tube passes. While such exchangers are widely used by the petroleum and chemical industries, they are not suitable for services involving two fluids, one heating and one cooling, over wide temperature ranges resulting in large temperature crosses. For example, in a certain low temperature process, in the interest of conserving refrigeration, it becomes most desirable to allow one process stream to be cooled from 100 F. to —90 F. by a second stream warming from —120 F. to +90 F. That this duty cannot be satisfactorily fulfilled by a standard one-pass shell and two-pass tube-type exchanger is obvious to all heat exchanger designers. On the other hand, for such services, many designers have offered single-pass shell and single-pass tubes countercurrent exchangers provided with either packed shells, packed nozzles, or shell expansion joints to allow for movements due to thermal effects. For operation at low pressures and medium temperatures, such exchangers are quite satisfactory. However, for high pressure and high temperature service or high pressure and low tem-

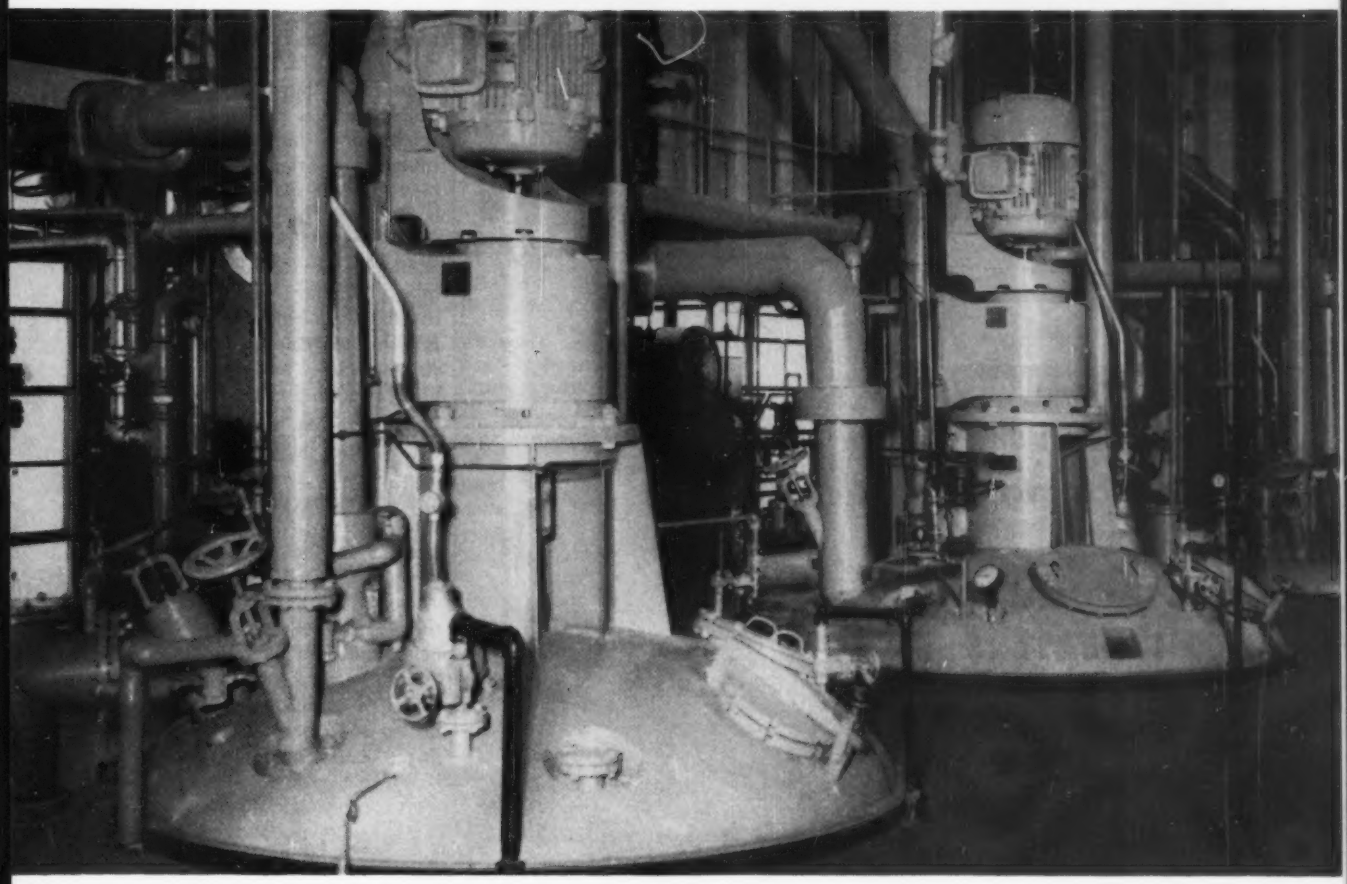
$$ Your Ideas Are Valuable! $$

At least $10.00 will be paid for each idea accepted for "How To Do It." All you need to do is write a brief note telling about your idea, then attach a photo or sketch (if needed), and mail it to Editor, Petroleum Refiner, P. O. Box 2608, Houston.

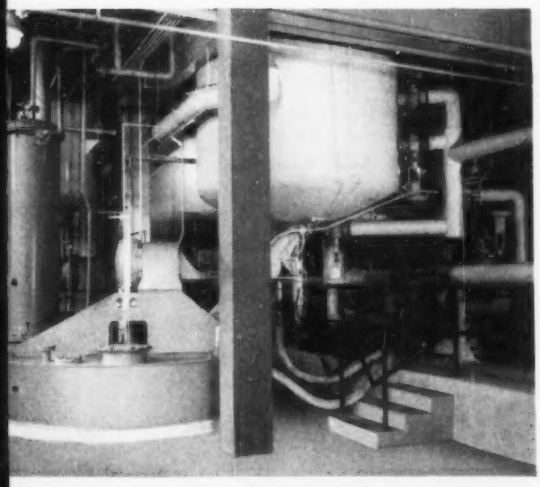
HERE'S PUSHBUTTON

VERSATILITY

in processing synthetic polymers for RINSHED-MASON at Detroit



Patterson SYNTHETIC RESIN SYSTEMS



In Rinshed-Mason's manufacture of the new high quality acrylic finishes for today's automobiles, Patterson synthetic resin processing equipment has a vital role. Pushbutton automatic from raw material feed to product discharge, the operation is controlled from a single panel. One common loop provides the hot liquid for heating four reactors. By means of individual recirculation systems, the jacket temperature of each reactor may be controlled precisely for operating between 100°F and 600°F. The installation, including 3 resin systems, a pilot plant, and all process piping, was furnished complete through start-up by Patterson. ● Let us show you what modern Patterson synthetic processing systems can do to improve profits in *your* operations. Write!

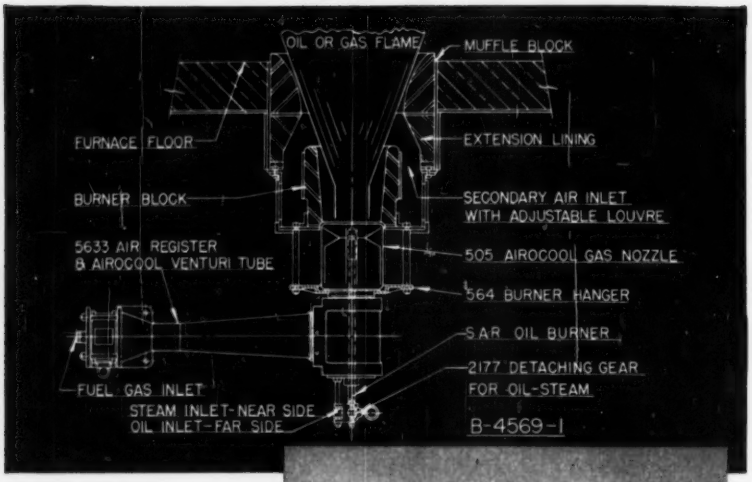
THE *Patterson* FOUNDRY AND MACHINE COMPANY

A Division of Ferro Corporation

East Liverpool, Ohio

THE *Patterson* FOUNDRY AND MACHINE CO. (CANADA) LTD.

Toronto, Ontario

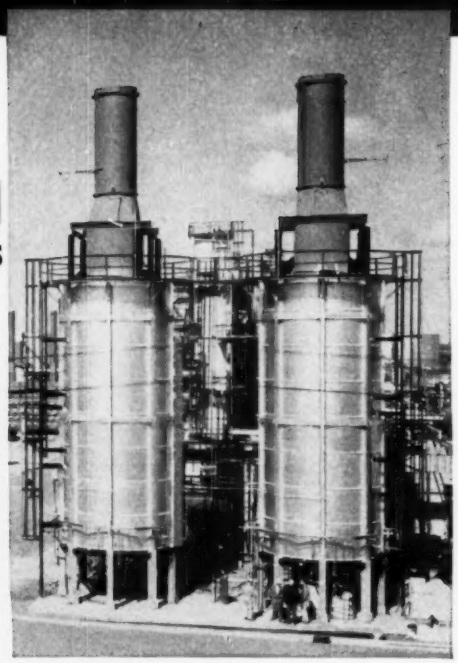


NATIONAL AIROIL

C-P GAS & OIL UNITS

Upfiring

LARGE CIRCULAR OIL HEATERS



These modern Struthers Wells twin furnaces-heaters are located in a major oil refinery in Western Canada. They are vertically fired each with a compact group of *National Airoil* natural draft, high heat release *C-P* combined fuel burner units.

These *C-P* units are designed to realize the greatest combustion economy together with flame mass centrally concentrated for a large proportion of heat to be transferred by flame radiation to the oil tubes thus avoiding destructive flame impingement on the tubes.

Their ease of regulation and combustion control contribute to their overall acceptability.

Ask for our Bulletin #498.

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INDUSTRIAL OIL BURNERS, GAS BURNERS, FURNACE EQUIPMENT

perature service, they have serious shortcomings, such as possible leakage of flammable fluids at packings or failures of expansion joints.

New Design. The new heat exchanger design is shown schematically in the Figure. The shell side is essentially the same in design as any floating head type exchanger. Differences exist mainly in the tube bundle and channel. As shown in the drawing, the tube bundle is provided with a large center tube rolled or welded into the tube sheets. After the bundle is assembled into the shell and the channel is bolted on, a removable center pipe is slid through the center hole in the channel cover into the fixed center tube in bundle. With proper gaskets, the flange of this removable center pipe is then held tightly between the channel cover and the flange of the line by bolting.

In operation, if the hot stream flowing in the shell side enters at the lower nozzle near the floating head and leaves at the upper nozzle, the tube side cold fluid will enter the channel at the upper nozzle, flow through the small tubes in the bundle as well as the narrow annulus between the two center pipes into the floating head, and then leave the floating head and the exchanger via the removable center pipe. To prevent any significant heat transfer between the floating fluid in the center pipe and its annulus, the removable center pipe is provided with a concentric thermal sleeves.

An exchanger of the design shown in the Figure has the following advantages.

- The flow pattern of the two fluids is strictly countercurrent.
- The efficiency is high, because the available temperature difference driving force is fully utilized.
- The mechanical construction is sturdy, and no packings are required.
- Both the tube bundle and the center tube are free to move and no undesirable thermal stresses can occur.
- Routine maintenance is easily performed since all parts are readily disassembled.

Exchangers of this design have operating pressures above 350 psig and operating temperatures range from a low of —130 F. to a high of +800 F. The service record of these exchangers have been excellent. No special effort

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Complete SCOPE of WATER CONDITIONING SERVICE from...

ALLIS-CHALMERS

End algae problems

easy, low-cost way

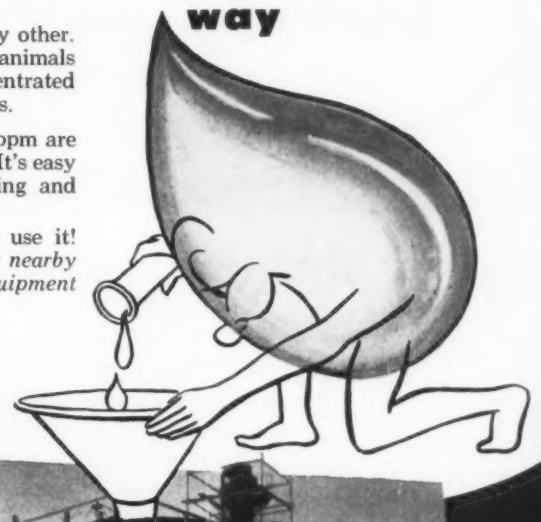
Eliminate problems of plugged pump strainers, coated heat-exchanger tubes and coated slots in cooling towers.

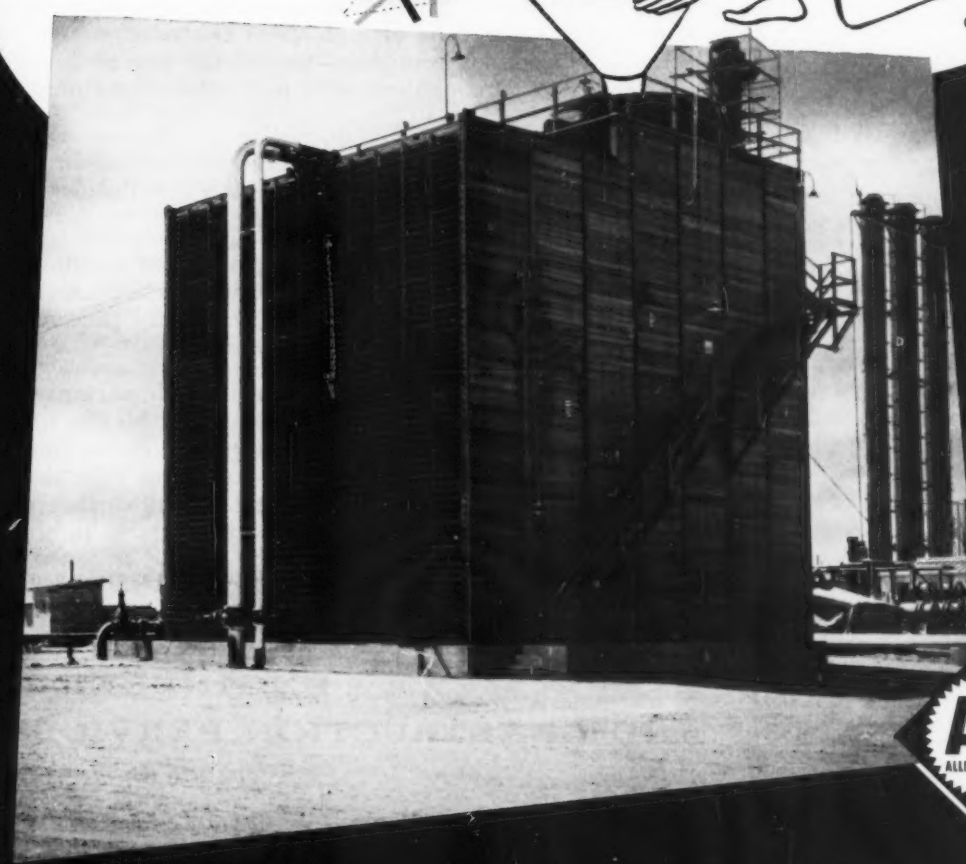
Control is safe . . . quick with Allis-Chalmers No. 120 Series Algaecide.

This algaecide is toxic to more algae than any other. On the other hand, it has low toxicity to fish or animals and is extremely safe to handle. Even in concentrated form it is only a mild irritant to skin and hands.

A little goes a long way! Only 2 to 5 ppm are required for effective dosage of most organisms. It's easy to feed into the system . . . and is non-oxidizing and corrosion inhibiting.

No water conditioning specialist needed to use it! Buy it and try it. *Purchase directly from your nearby A-C office or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin.*





A-C ALLIS-CHALMERS

A 5972 C & P

A good question for men planning a new plant...

How can you select the best contractor for your job?

WE ALL work with the same tools—all employ top-flight talent—all have long experience and broad capabilities. But, if it is your responsibility to select an engineering-construction company, it will pay you well to dig deep into facts like these:

- McKee engineers work with the newest time-saving equipment, under ideal conditions, in quarters designed for maximum efficiency. They employ the latest type of high-speed electronic computers for rapid solution of complex problems—use all the practical, time and money-saving methods consistent with high quality engineering and construction.

- McKee has always attracted high-calibre engineering brains. Our specialized technical staff has contributed many new developments in methods and practices for the industries we serve.

- Our experience covers 54 years of designing and building plants worth 1½ billion dollars for the steel, petroleum, chemical and non-ferrous metals industries all over the world. Eighty percent of our work is repeat business from satisfied customers.

- All these are important factors, but, equally important are the integrity and business policies of the firm you hire. McKee makes no impossible promises, sets no impractical completion dates. Our efforts are directed toward a single objective: to transform your new-plant expenditure into a profit-earning investment at the earliest possible date. We'll welcome an opportunity to give you further information.

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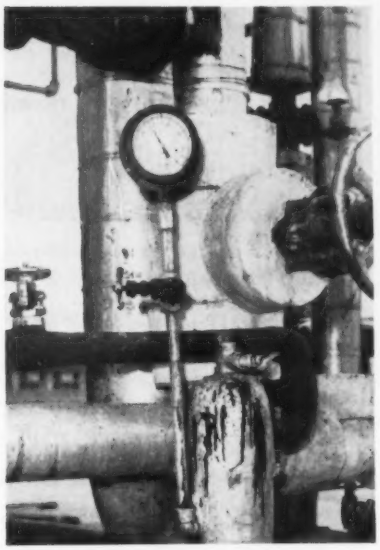
McKEE ENGINEERING AND CONSTRUCTION SERVICES

is needed to eliminate leaks and obtain tight joints.

This idea was submitted by Morgan C. Sze, Hydrocarbon Research, Inc., New York.



Water Between Gage and Hot Asphalt Keeps it Cool

A simple method of insulating hot asphalt lines so the pressure can be read on the gages is used at the Petroleos Mexicanos Salamanca refinery. The hot asphalt tap line is insulated and connected to the side of a closed vessel of approximately five liters capacity. A line leading out of a point near the bottom of the vessel is carried up to the pressure gage which is placed at a convenient height. The pot is then filled with fresh water and the pressure from the asphalt line turned on. By having the pressure connected through the pot of water with the hot line on top, no temperature can reach the gage and the piping can not clog up as the insulation on the upstream side of the pot keeps the asphalt above the pour point.

Silica Gel Holds Answer To Dampness in Sand

When sand gets damp, the sanders on locomotives do not work and thus create a safety hazard when the sand is needed to brake the train. Yet, the emptying of sand boxes in locomotives to dry the sand is time-consuming and wasteful.

The solution is to put some bags of

R-P&C bar stock valves

rugged, compact, economically priced

1. These valves are made from high quality bar stock to withstand high pressure service.

2. Compactly designed, R-P&C Bar Stock Valves are particularly advantageous for close coupled installations in instrument lines or on panel boards.

3. Although designed for control service, the construction of these valves is suitable for general purpose as well.

4. Special techniques, developed by R-P&C for manufacture of Bar Stock Valves, permit these valves to be priced lower than conventional Forged or Cast Steel Valves for similar service.

NOTE: *Valve No. 1070 in ¾" and 1" sizes has renewable seats and discs*

R-P&C Bar Stock Valves are especially recommended for meter, gauge, sampling, or test valves on equipment requiring a reliable, compact valve to withstand high pressure service.

In addition to bar stock valves, our R-P&C distributors offer you a complete line of R-P&C gate, globe and angle valves in all standard materials: bronze, electric furnace iron, cast steel, forged steel... plus specialties for many uses.

See him—or write

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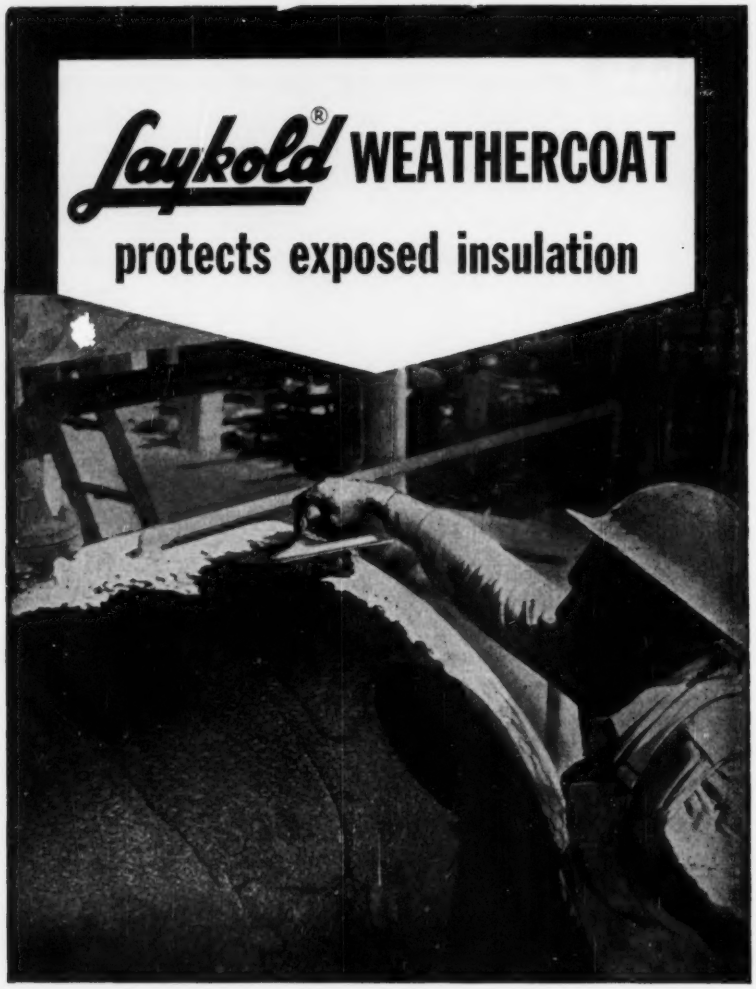

INSULATION on towers, tanks and exchangers must be kept DRY. If moisture gets through, the efficiency drops.

Modern refinery and plant design places many major insulated vessels "in the open." You can maintain the efficiency of your insulation with easy-to-apply Laykold Weathercoat.

Weathercoat is a fibrated asphalt-base material of easy troweling consistency that dries to a black, remarkably tough and tenacious coating. A majority of the leading refineries are regular users of Weathercoat.

A new product: Mastic Weathercoat, a bodied material, for use wherever economy demands the application of a *single*, thick layer.

Write today for free illustrated brochure, entitled "Laykold Weathercoat for Insulation Protection."

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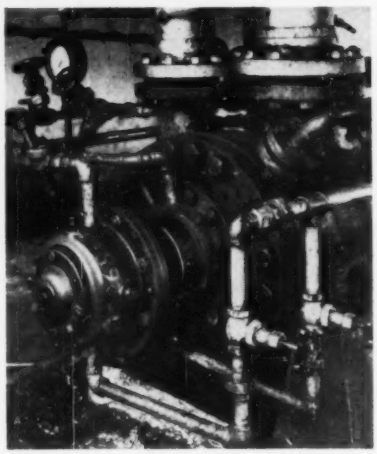
How To Do It . . .

silica jel in the bottom of the sand boxes. The silica jel will absorb moisture and thus prevent moist sand from clogging the sand pipes. The silica jel will also eliminate the removal and rodding out of sand pipes, which is quite common before the addition of silica jel. This idea was submitted by E. R. Beaston, Ethyl Corp., Pasadena, Texas.

Increase Life of Plant Engines With Simple Plate

This idea can save you quite a bit of money by increasing the life of plant equipment engines.

A plate is drilled (three 13/16-inch holes) and inserted between the carburetor and manifold on the towmotor engines. This plate will govern the engine R.P.M.'s down to the factory recommended speeds. This idea was submitted by Carnie Berry, Ethyl Corp., Pasadena, Texas.



Heavy Lube Oil Will Stop Mechanical Seal Leaks

In Pemex's Salamanca refinery, a slick way of preventing leakage through the mechanical seals of a liquid propane pump was discovered. Heavy, waxey lube oil was piped to the outside of the steel under approximately the same pressure as the propane. No leaks occurred. The heavy lube oil was relatively easy to seal, and the hard-to-hold propane was easily managed. The propane pump works at approximately 600 psi and at 120 F. This is below the pour point of the heavy lube oil.

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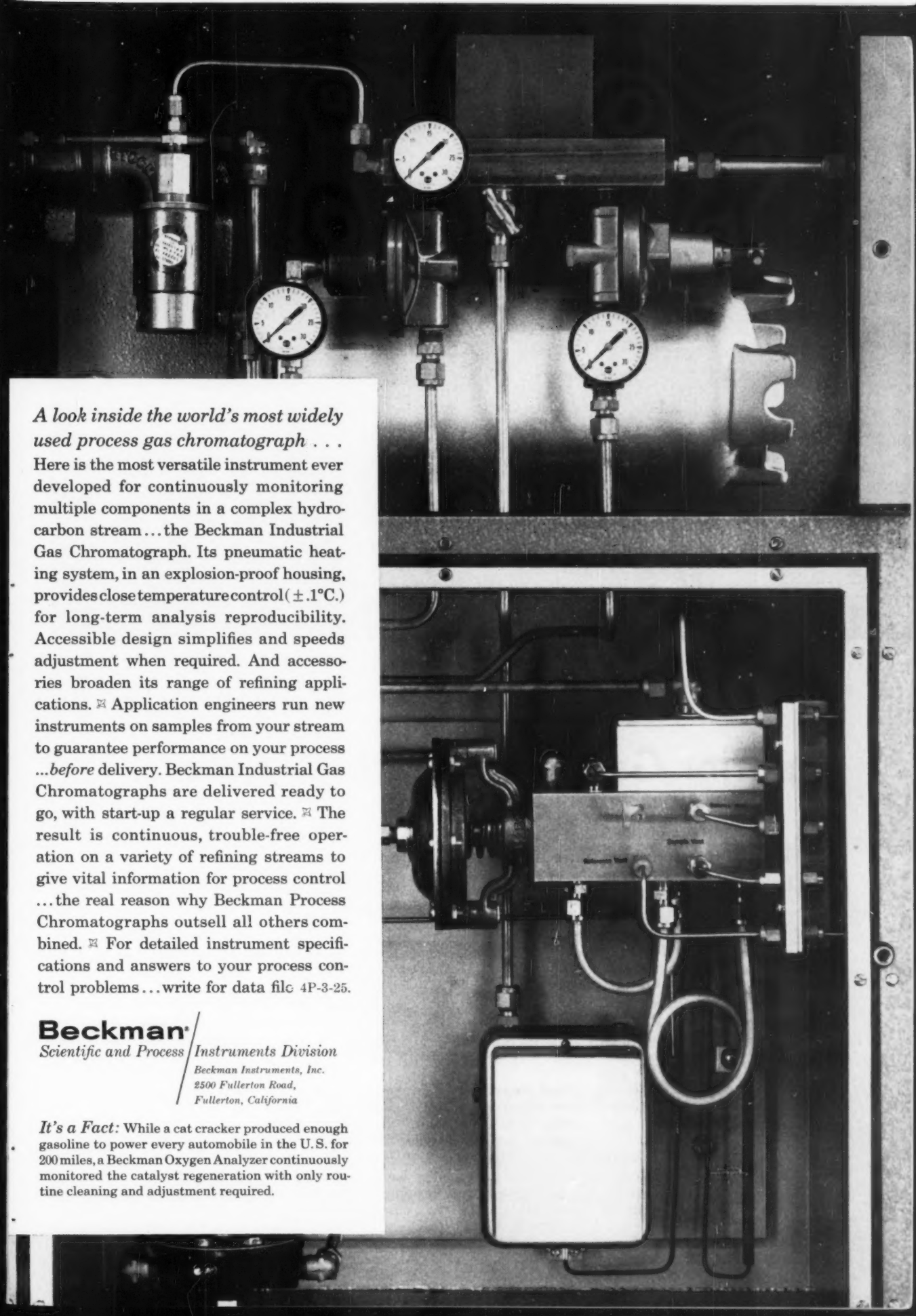

A look inside the world's most widely used process gas chromatograph . . .
Here is the most versatile instrument ever developed for continuously monitoring multiple components in a complex hydrocarbon stream . . . the Beckman Industrial Gas Chromatograph. Its pneumatic heating system, in an explosion-proof housing, provides close temperature control (±.1°C.) for long-term analysis reproducibility. Accessible design simplifies and speeds adjustment when required. And accessories broaden its range of refining applications. ⌘ Application engineers run new instruments on samples from your stream to guarantee performance on your process ...*before* delivery. Beckman Industrial Gas Chromatographs are delivered ready to go, with start-up a regular service. ⌘ The result is continuous, trouble-free operation on a variety of refining streams to give vital information for process control ... the real reason why Beckman Process Chromatographs outsell all others combined. ⌘ For detailed instrument specifications and answers to your process control problems ... write for data file 4P-3-25.

Beckman
Scientific and Process Instruments Division
Beckman Instruments, Inc.
2500 Fullerton Road,
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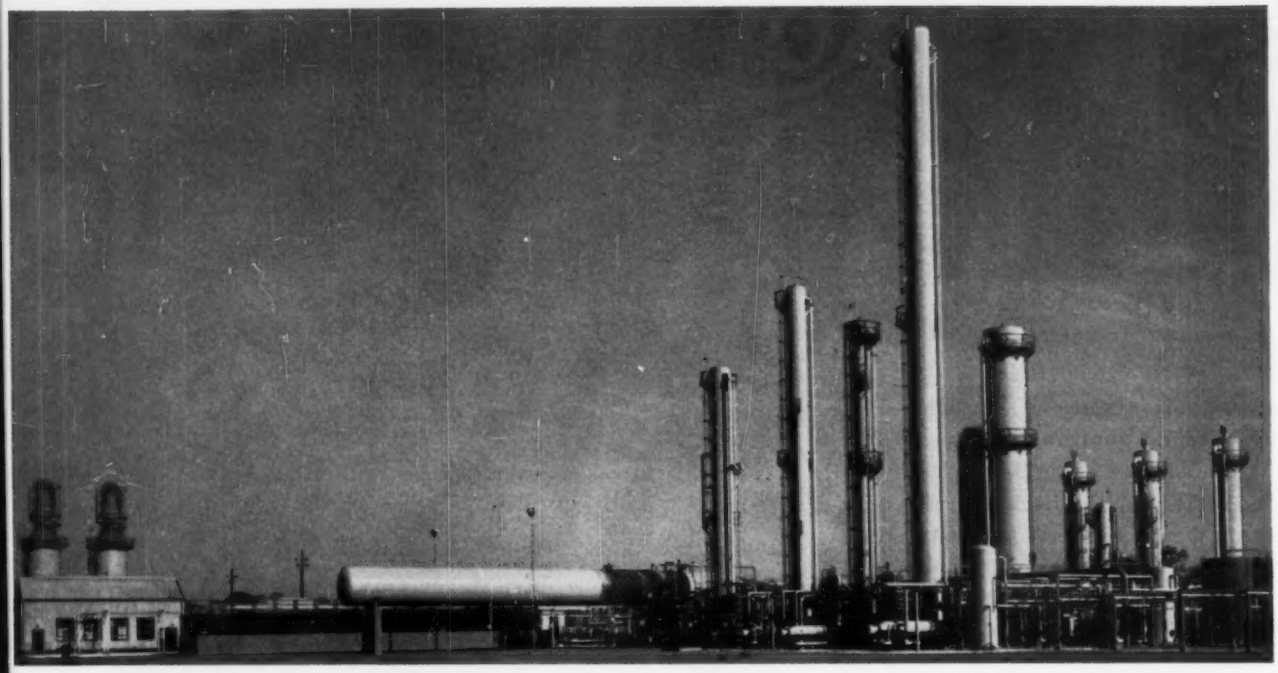
It's a Fact: While a cat cracker produced enough gasoline to power every automobile in the U.S. for 200 miles, a Beckman Oxygen Analyzer continuously monitored the catalyst regeneration with only routine cleaning and adjustment required.



Lowry, La., plant processes 300 MMcf of gas per day. In operation since last October, it's among Louisiana's largest.

Superior Gas Plant Features Color

Louisiana processing unit uses aluminum with a baked enamel finish for insulation jacketing

Lowry gas processing plant, designed and constructed for Superior Oil Co. by Hudson Engineering Corp., adds a new touch of color to the Southern Louisiana area. Pre-enameled aluminum jacketing in soft pastel colors, with brighter colors on pipe and safety ladders, form a pleasing combination in this modern gasoline plant.

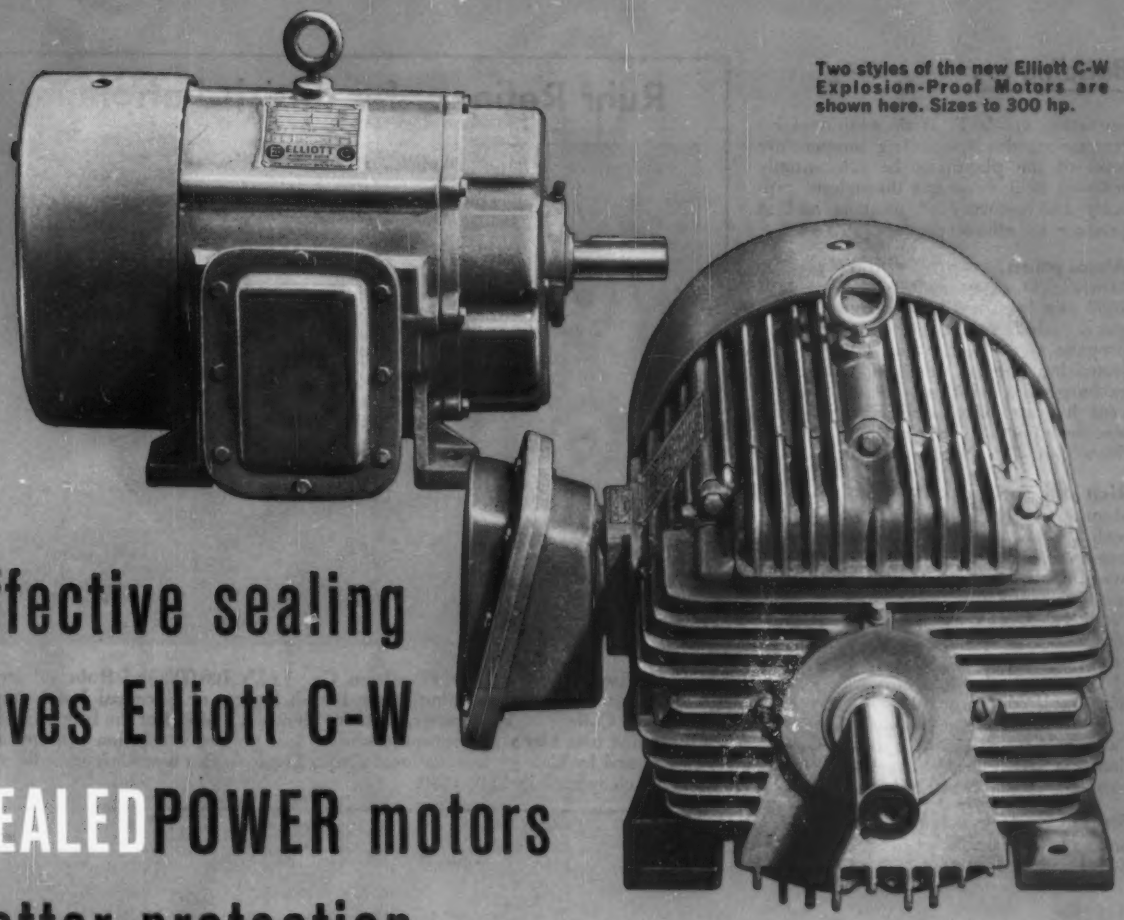
Colored Aluminum. Aluminum with a baked enamel finish was used extensively for insulation jacketing. The plant is of the refrigerated absorption type, so practically every vessel and pipe line required either "cold" or "hot" insulation. Colored aluminum was selected instead of the natural aluminum jacketing for all insulated equipment.

Plant Operation. The Lowry plant was placed in operation in October, 1958. Although designed to recover only 60 percent propane, the plant extraction is well over 70 percent at design gas dates and it has been in uninterrupted operation since startup.

Facilities, located in Cameron Parish, La., were designed to provide for hurricane winds, heavy rains and high water common to the area. Vessels and foundations were built to withstand 150-mph winds and the entire plant area was surrounded with a dyke about two feet higher than the highest recorded river level.

Gas Processing Plant. Superior's new plant is among the largest in Southern Louisiana, capable of processing over 300 MMcf per day. The design utilizes refrigerated absorption with dehydration accomplished by glycol injection into the gas being chilled.

Although the plant is designed to operate at 0 F, all vessels, exchangers, pipe, valves, and fittings in cold service are constructed of alloy or aluminum-killed steel and designed for



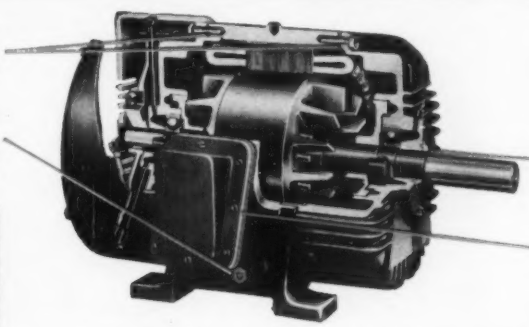
Two styles of the new Elliott C-W Explosion-Proof Motors are shown here. Sizes to 300 hp.

effective sealing gives Elliott C-W SEALEDPOWER motors better protection against moisture, dust, fumes, corrosion

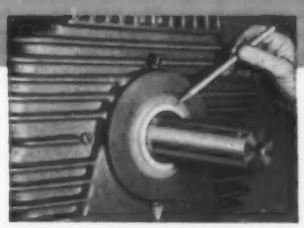
LONG, SNUG BRACKET SEAL. Close-fitting, deep rabbet provides explosion-proof type seal for all SEALEDPOWER motors.

EASILY ACCESSIBLE, automatic breather and drain plug, underwriters approved, for removing internal moisture accumulations.

NEW DATA on the complete line of Elliott C-W SEALEDPOWER motors is given in Elliott Bulletin PB 6000-2. Send for free copy today.

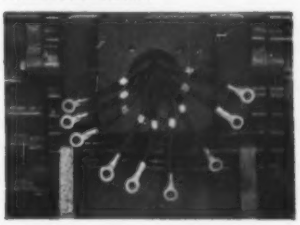


Elliott explosion-proof motor—underwriters approved.



ROTATING SLINGER PREVENTS entrance of dirt and moisture through the bearing and shaft opening.

NO LEAKAGE HERE. Tightly sealed leads and opening. Metal-to-metal fit between conduit box, frame and cover.



ELLIOTT Company

Crocker-Wheeler Plant Jeannette, Pa.

operation at—50 F. With additional refrigeration, the operating temperature level of the plant can be substantially reduced to increase gas throughput capacity and recovery of propane and to produce an ethane product.

Absorption. Approximately 300 MMSCF/D of gas enters the plant at 1050 psig from field separator units. The gas is exchanged and chilled to 0 F using propane as the refrigerant. Glycol is injected into the gas stream flowing to the exchangers to dehydrate the gas and prevent hydrate formation. This glycol is scrubbed out of the gas before the gas flows into the absorber.

Rich Oil Turbines. Rich oil from the absorbers, containing the desired light hydrocarbons, is reduced in pressure in two-stage flash operations. The energy available from these pressure reductions is not wasted across a control valve, however, but is used in two "rich oil turbines" to drive other pumps in the process. These turbines recover over 125 hp of energy which would otherwise require direct fuel consumption.

After partial demethanization by stage flashing, the rich oil flows to an oil fractionator. This vessel demethanizes and partially deethanizes the rich oil.

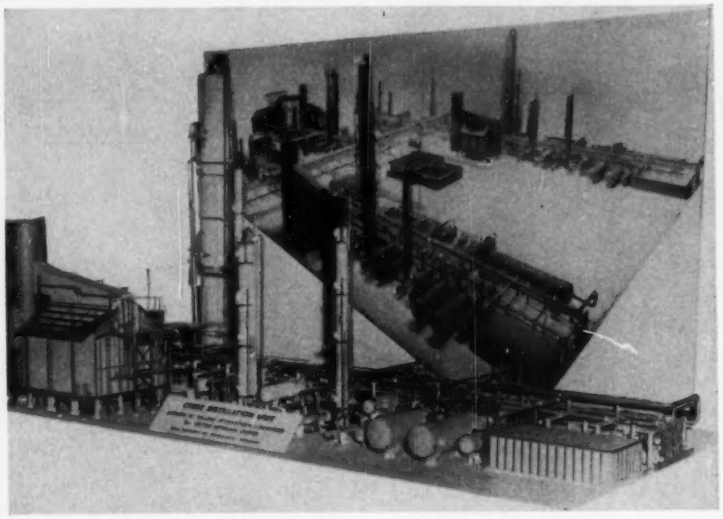
Stripper. Oil from the demethanizer flows to the stripper where the desirable hydrocarbon product is removed by distillation. Oil from the base of the stripper is pumped through direct fired heaters and partially vaporized.

These oil vapors are the stripping medium used to remove the light hydrocarbons from the oil. Two oil heaters were used, each for 60 percent of design capacity, to provide operational flexibility and ease of maintenance. Oil from the base of the stripper, which is pumped through the heaters, is first used in reboilers and exchangers as a heating medium throughout the plant. No steam or other outside heat is required. The oil heaters thus provide stripping vapor plus plant heat requirements. Lean oil from the stripper flows through exchangers to the lean oil circulation pumps. Two gas engine driven pumps are installed, each for the design oil circulation rate.

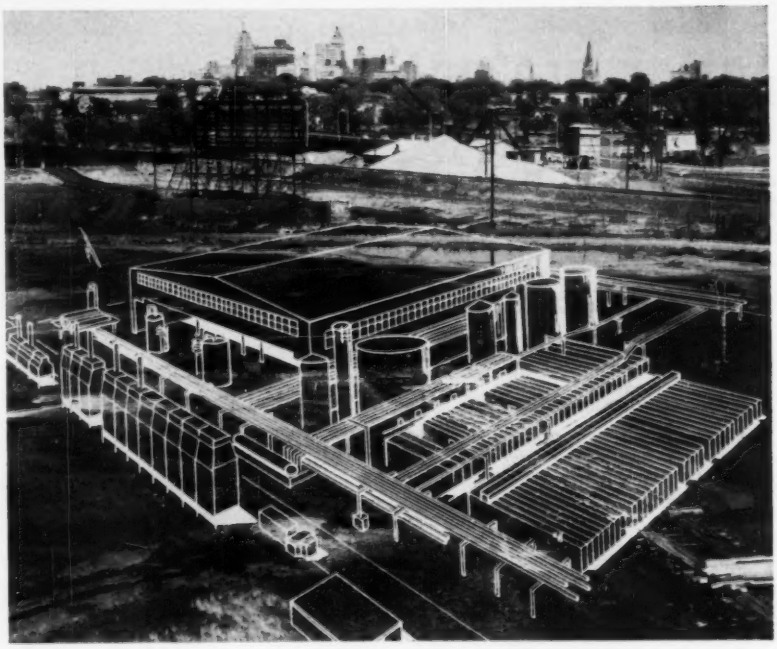
Product Fractionation and Storage. Light hydrocarbon products stripped from the oil are pumped through a conventional fractionation train. Four fractionators are used—a deethanizer, depropanizer, debutanizer and deisobutanizer, to produce propane, iso-butane, normal butane, and gasoline. Because most of the plant products are shipped by barge, ten days storage capacity was included.

Loading Facilities. The plant is located on the Mermentau River, about a mile from the Intercoastal Canal, so products may be readily shipped by barge. A barge loading slip and dock were included with pumps and loading facilities for two barges.

Ruhr Refinery for British Petroleum



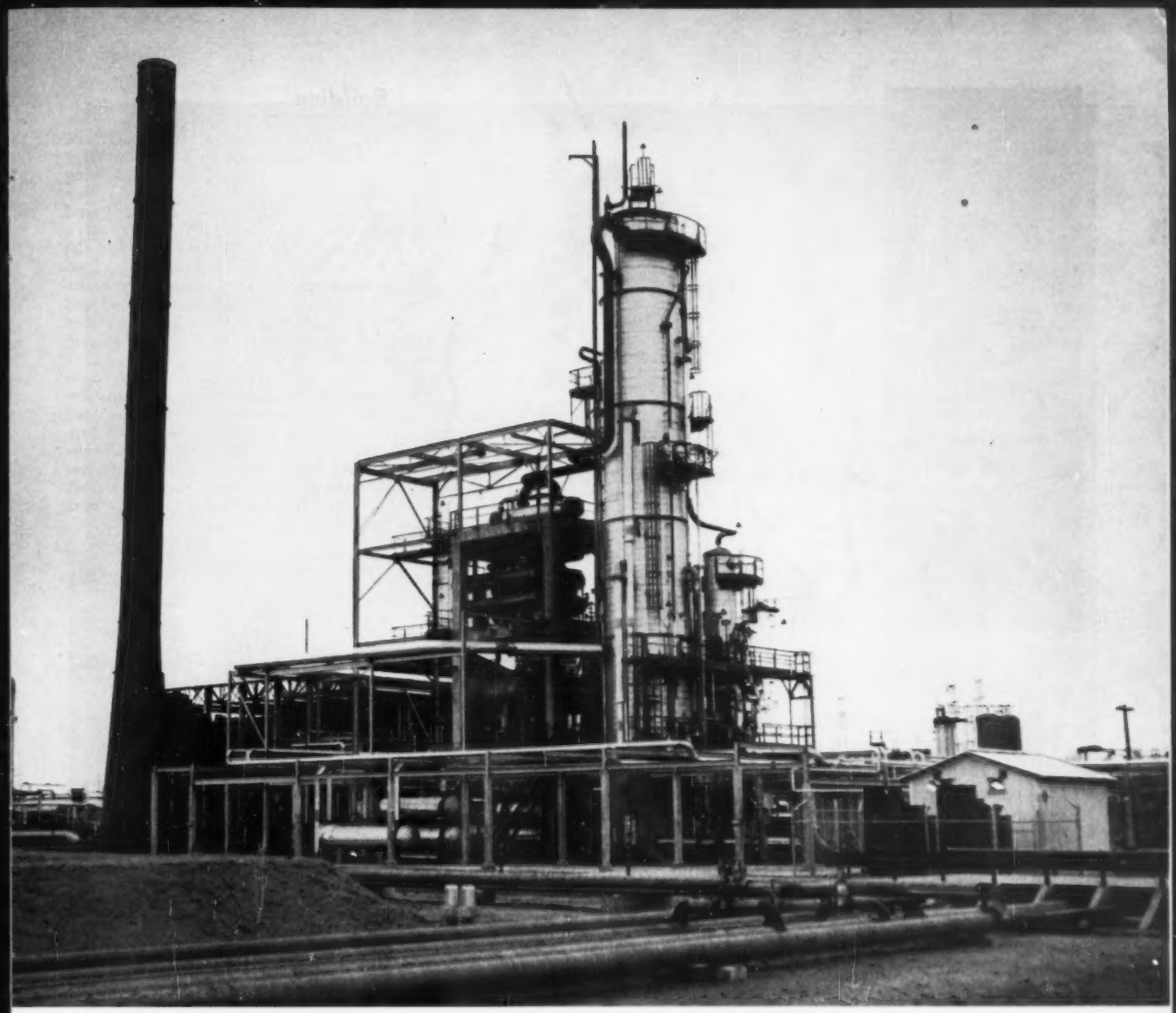
This first view of British Petroleum Co., Ltd.'s 100,000-bpd Ruhr refinery was shown at a recent meeting of the British Society of Chemical Industry at Battersea College of Technology, London. Shown is a model of the future crude distillation unit and a photograph revealing how the process section will appear as designed by Kellogg International Corp., London. This new German refinery will be completed in Fall, 1960.



Sunray Plans New Tulsa Dewaxing Plant

DX Sunray Oil Co. plans to build a $7-million solvent dewaxing plant at its Tulsa refinery, with construction to start September 1 and be completed by August, 1960. When started up, the new addition will make the firm one of the world's largest producers of microcrystalline wax.

The dewaxing plant, to be built by Foster Wheeler Corp., will not increase lubricating oil output, but will reportedly produce oils at higher efficiency and lower cost. New facilities will nearly double Sun-



HESS TRADING AND TRANSPORT UNIT COMPLETED IN SEVEN MONTHS FROM START OF ENGINEERING

A crude distillation unit and a complete utility system—the basis of a new refinery—has been designed, engineered and constructed by Lummus for Hess Trading and Transport, Inc., Port Reading, New Jersey, in exactly seven months.

Engineering was begun on April 1, 1958 and on November 1, 1958 the refinery was ready for operation. Twenty-one days after crude was charged, the performance tests for the unit were successfully completed and the unit has been operating at capacity on various charge stocks.

Lummus designed the unit to assure a general-purpose refinery which is capable of processing various types of crude.

In addition to the crude distillation unit, the off-site facilities include: a complete electrical system, a water cooling and circulation system, steam generation equipment, waste water system, TEL blending and dyeing system, instrument air, plant air, fuel gas, and fuel oil systems. All were designed by Lummus to allow for future expansion.

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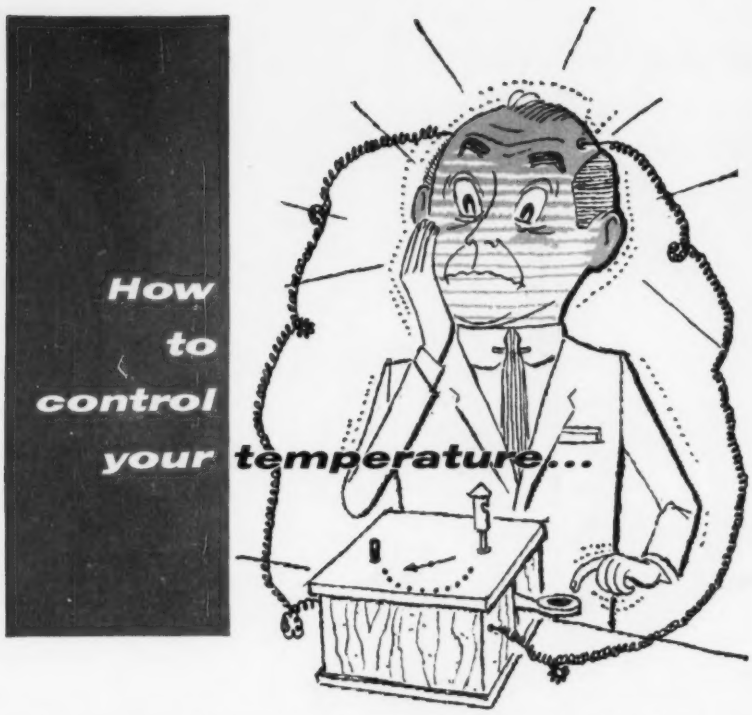

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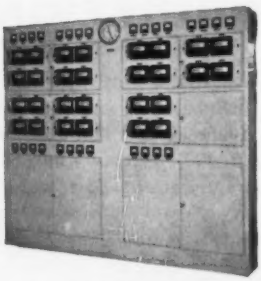

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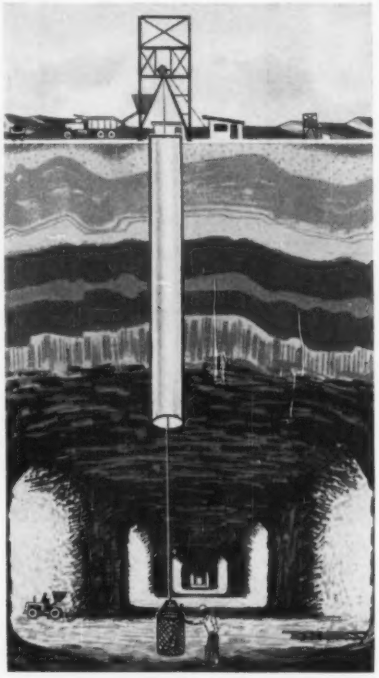
Building . . .

ray's present output of industrial wax, and produce microcrystalline wax in large commercial quantities. The new dewaxing unit will push the company's annual wax production beyond the 70-million pound mark.

Covering about 100,000 square feet, the addition will have 12 of the largest continuous rotary filters designed for dewaxing service. It will require 2,000 tons of refrigeration, 5,000 turbine horsepower and will contain more than 1-million pounds of pipe.

The plant is a fully integrated operation and will produce lubricating oils and finished waxes simultaneously from the same charge stock. It will replace three separate dewaxing plants in operation at the Tulsa refinery and will manufacture five different grades of wax. The charge stock will be oil fractions from select Oklahoma crudes.



Huge Underground Storage Cavern for Wood River

Field work has been started at Shell Oil Co.'s Wood River, Ill., refinery on what will be on of the country's largest mined underground caverns for storage of petroleum products. The picture shows an artist's conception of the project.

More than 450 feet underground, the cavern will measure 300 feet wide by 400 feet long. It will consist of a series of interconnected tunnels each 25 feet wide and 35 feet high. Forty-foot square pillars of undisturbed rock will separate the tunnels and form the roof support. The cavern, expected to be completed by mid-1960, is about 1,000 feet east of the refinery's present facilities. Stored in the cavern will be up to 420,000 barrels of butane. It will enable sufficient stocks to

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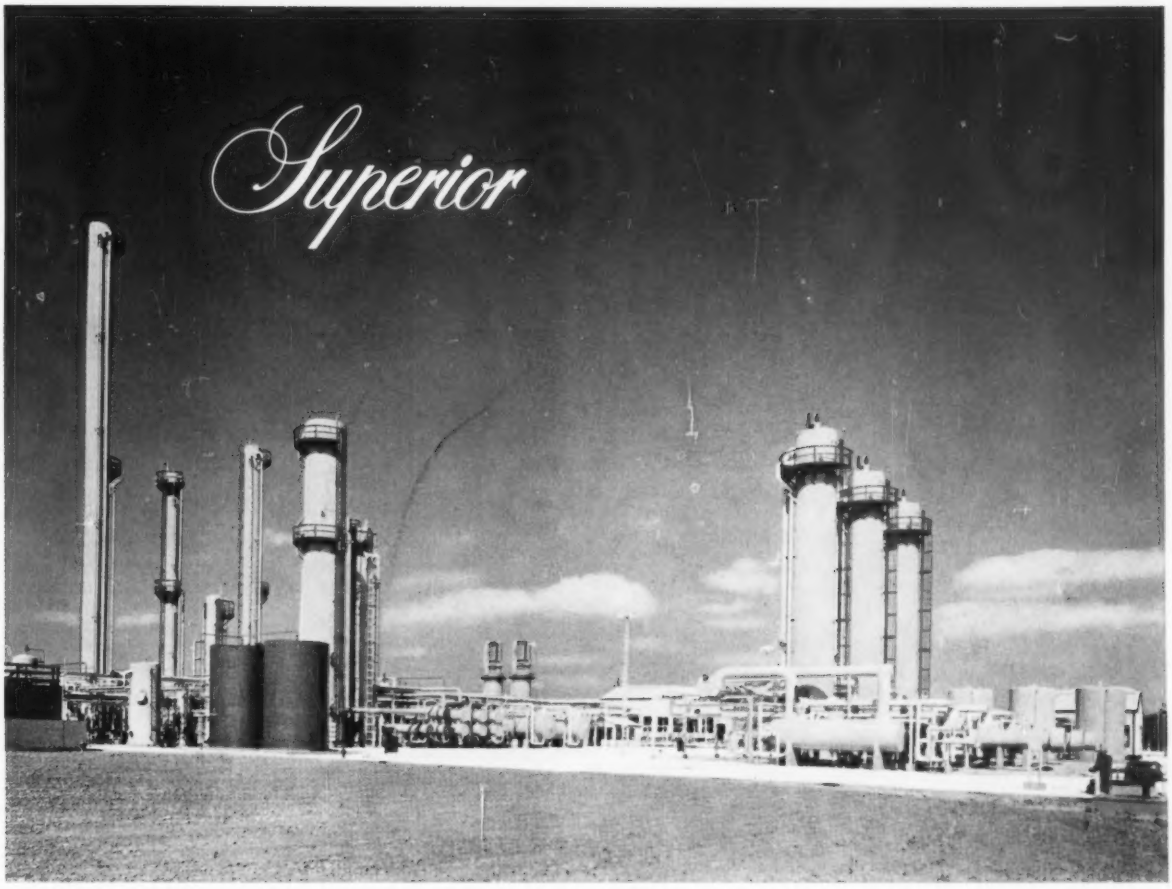

MORE THAN MEETS THE EYE

Pastel and bright color combinations used in this Hudson designed and built plant are utilitarian and also pleasing to the eye.

But beyond the eye appeal is the built-in 30 years experience of Hudson in building gas processing plants in most gas producing regions of the free world.

Such experience combined with constant alertness for improvements results in trouble-free plants, built on time, with careful balance between capital cost and operating cost to assure maximum return on the investment.

The above pictured absorption plant processing 300 million cubic feet per day of gas at about 1000 pounds pressure is located on the Mermentau River in Cameron Parish near the Louisiana Gulf Coast, and was designed and built for the Superior Oil Company.

A refrigerated absorption process is used with provision for future further refrigeration down to minus 50°F to increase gas throughput and/or product recovery. The plant has operated uninterruptedly since initial test start-up in October 1958.

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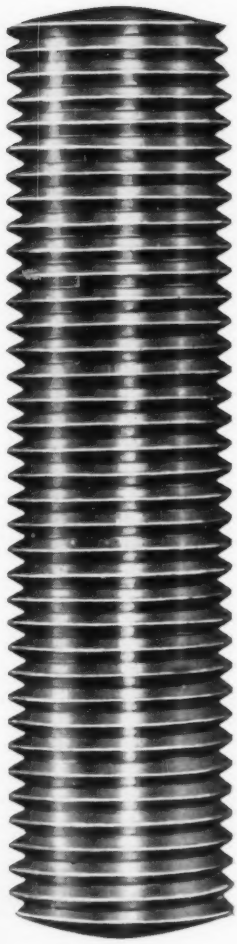
There's nothing ordinary about the fasteners illustrated on this page. Bethlehem engineers designed them to resist the high and low temperatures—and the high pressures . . . of refinery bolting. You can depend on them for long life, low maintenance. Full details gladly supplied by our nearest sales office. Or write to us at Bethlehem, Pa.



Bethlehem continuous-thread stud has no point of thread run-out. Stresses can't concentrate at any specific area. Instead, stresses are evenly distributed over the full working length of the stud.

One of these four nuts meets your temperature or pressure requirements. Each meets ASTM Spec. A-194. Each is tapped to Class 2B fit. Each is available in the full size range.

Grade 4, severe temperatures and pressures.

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Building . . .

be accumulated in the summer to meet the winter demand for butane.

The first steps in construction will be the drilling of two holes, each 50 inches in diameter, about 500 feet deep. Steel pipe 42 inches in diameter will be lowered into each hole and cemented in from top to bottom. Men and equipment will be lowered through these 42-inch openings. Large equipment will be dismantled above ground, lowered piece by piece, and reassembled on the cavern floor. Removal of all rock and debris will also be made through the 42-inch openings.

In addition five smaller shafts will be drilled to be used for venting the cavern. Once it is completed, two of these holes will be used for pumping purposes.

Butane will be pumped in from refinery operating facilities and discharged by two pumping units in the cavern floor. The man-made cavern will be built in limestone formations. About 175,000 tons will be removed to create storage space, and the remaining rock will make up supporting pillars. Contractors for the job are Fenix and Scisson, Inc., Tulsa.

Texaco, Inc. has started construction of a sulfuric-acid type alkylation unit and a butane isomerization unit at its Tulsa refinery. The alkylation unit will have a capacity of 2,050 bpsd of high octane alkylate, and the isomerization unit will have a capacity of 600 bpsd of isobutane production. The site has been cleared and contracts have been awarded for many phases of construction, which is to be complete by November, 1959.

Tidewater Oil Co. has installed what it believes is the world's largest floating roof tank, at its Delaware refinery 15 miles south of Wilmington. The first of two being constructed, it has a capacity of 274,000 barrels of crude oil and is made of formed steel plates ranging up to 1½ inches thick. The tanks will be 56 feet high and have a diameter of 187 feet. Built by Graver Tank and Manufacturing Co., the two tanks will provide the refinery with storage facilities for 2,148,000 barrels of crude oil.

Phillips Chemical Co. has completed the last stage of expansion at its Borger, Texas, synthetic rubber plant. Manufacturing, pilot plant, research, maintenance and warehouse facilities have been streamlined to complete an expansion started in 1955. The plant produces 108,000 long tons of synthetic rubber annually.

Derby Refining Co. has placed its new 1,700-bpd hydrofluoric acid alkylation unit on stream at Wichita, licensed by Universal Oil Products Co. and built by Procon, Inc. The unit completes an expansion begun in 1957. Design and planning was handled by Litwin Engineering Co. and Socony Mobil Oil Co. The over-all conversion included installation of a 25-million-Btu heater; enlarge-

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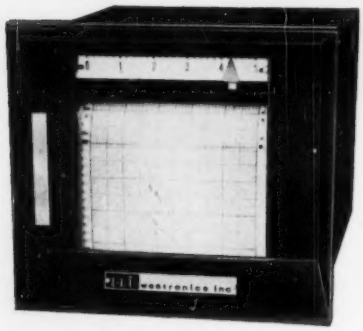

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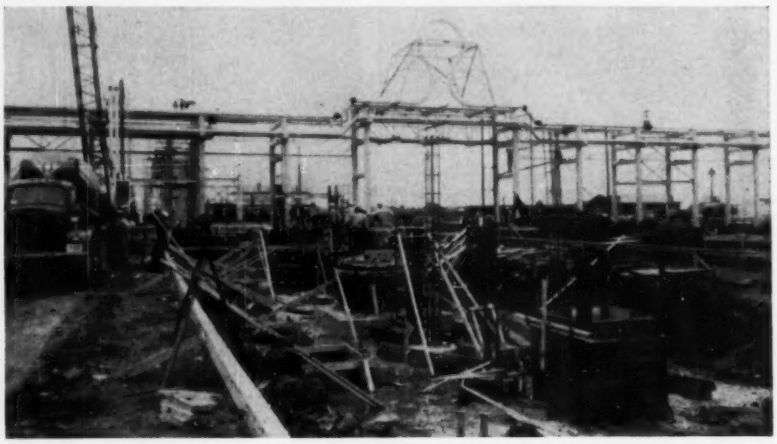
Building . . .

ment of liquid feed lines; replacement of old pumps with hot oil and feed pumps; a new 1,100-hp steam turbine; new heat exchangers, coolers and steam generating equipment; and a 600-hp gas-engine-driven compressor with an increase in number and size of gas lines. The changes increased flexibility and capacity of the catalytic polymerization unit, gas concentration plant and Thermofor catalytic cracker. The modernized unit has a 7,335-bpd capacity of fresh feed at 76 percent conversion, or 9,200 bpd at 66 percent conversion.



Kellogg Starts Work on Shell Phenol Unit

Construction of Shell Chemical Corp.'s new phenol unit at Houston has begun. Major concrete and structural steel foundations for the new chemical unit have been laid. The M. W. Kellogg Co. is handling design, engineering, materials procurement, and erection of the plant, with certain associated effluent facilities. Slated for completion late in 1959, the unit will produce acetone as a co-product. Shell will use most of the phenol to manufacture ingredients for its resins. Shell Oil Co. will also take a share.

Imperial Chemical Industries, Inc., plans to build a polypropylene plant at its Wilton, Yorkshore, England, facilities. I.C.I. currently manufactures the product only at a pilot plant.

Shell Chemical Co., Ltd.'s subsidiary, Petrochemicals, Ltd., is planning a polypropylene plant at Carrington, England. The new polyolefin unit is slated for completion in 1961.

Galensberg Benzin A.G. has upped the capacity of its refinery at Gelsenkirchen, Germany. The plant becomes the largest in Germany with the expansion, according to the company. Capacity went from 3.3 million tons per year to 4.5 million tons.

Scholven A.G. plans to build a refinery at Karlsruhe, Germany, along with four other German companies—DEA, Gelsenberg Benzin, Mobil Oil and Wintershall. The plant's initial capacity will be 2-million tons a year.

Venezuela will be the site for a new $2.4-million carbon black plant. Completion of the 20-million-pound-per-year plant, to be built at Moran, is slated for July, 1960. It will be constructed for the Negroven organization under a license agreement with United Carbon Co.

Shell Oil Co. plans to up the capacity of its glycerol plant at Pernis, The Netherlands. The expansion to 15,000 tons per year is slated for completion in early 1960. Shell's original Pernis plant was completed a year ago, and was the first

Jefferson Chemical Co. has completed its 60 - million - pound - per - year ethylene oxide plant at Port Neches, Texas. The unit was designed by Scientific Design Co.

Societe Belge de l'Azote et des Products Chimiques du Marley (SBA) of Liege, Belgium, has started construction to increase its styrene capacity. Work will be handled by the firm's Engineering division and Koppers, Inc. The plant will be built at Mazingfarbe in Northern France.

Fertilizers & Chemicals, Ltd. has started up its new nitric acid production plant at Haifa, Israel, constructed by the Engineering division of Societe Belge de l'Azote et Produits Chimiques due Marley (SBA) of Belgium.

Firestone Tire & Rubber Co. plans a $55-million expansion of its worldwide processing facilities over the next 30 months. U. S. investment will be $40 million. Included will be new plants at

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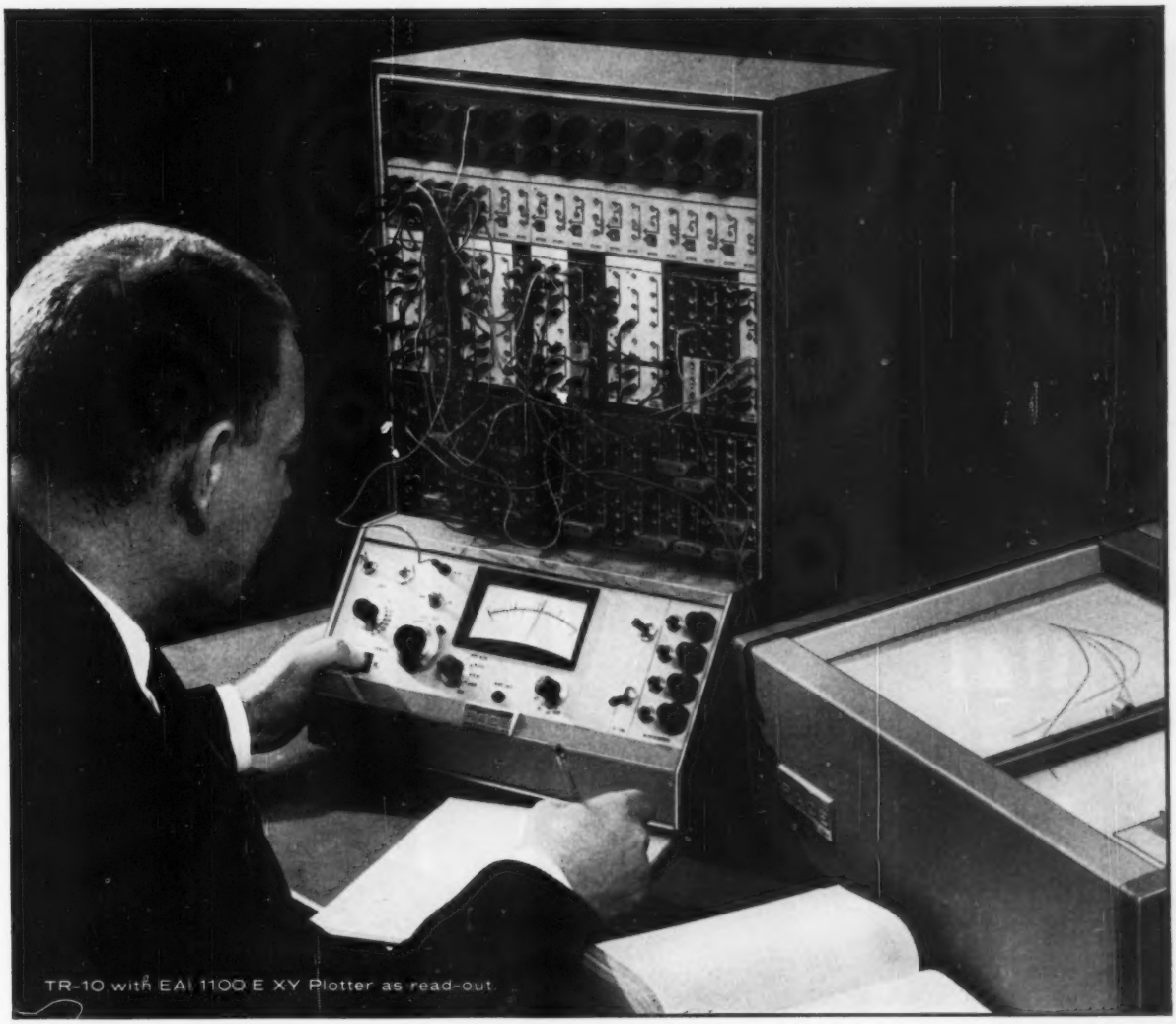

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Because of its minimum size and low price, the TR-10 can become your own personal analog computer. You gain first-hand experience with the power of analog techniques, and convert more of your time to *creative engineering*. New ideas that were too costly to try before are now practical. You can design virtually to perfection and have a permanent, visual record of performance before building pilot models or prototypes. As a result, "cut and try" expense is reduced.

The same quality workmanship and design that has made Electronic Associates the world's leading producer of precision general purpose analog computers will be found in this new unit. Accuracy to ±.1 per cent. Modular construction allows you to select varying quantities of the following computing functions: summation, integration, multiplication or division, function generation, parameter adjustment, logical comparison.

For complete engineering data, write for Bulletin TR-10-L.

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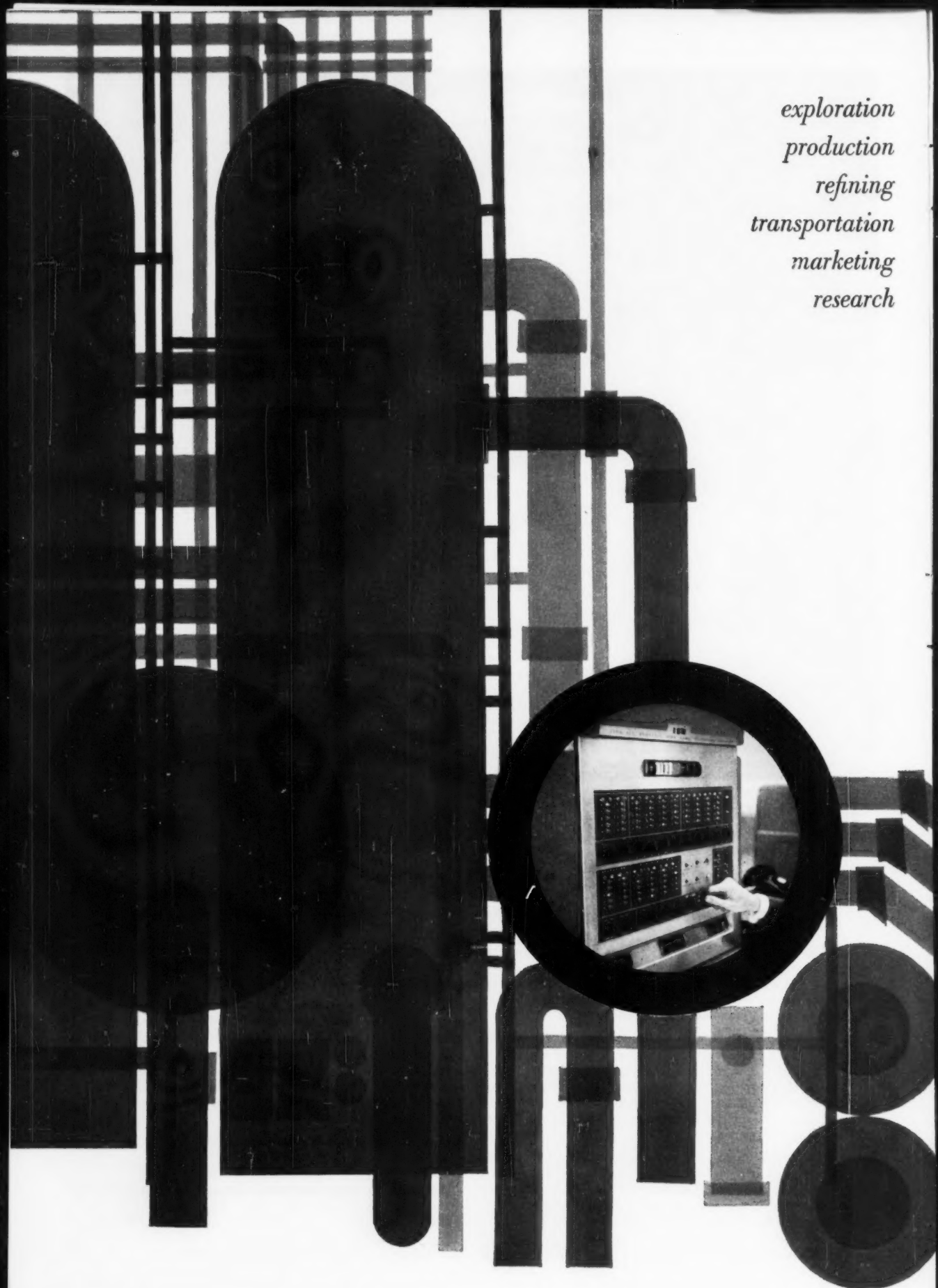
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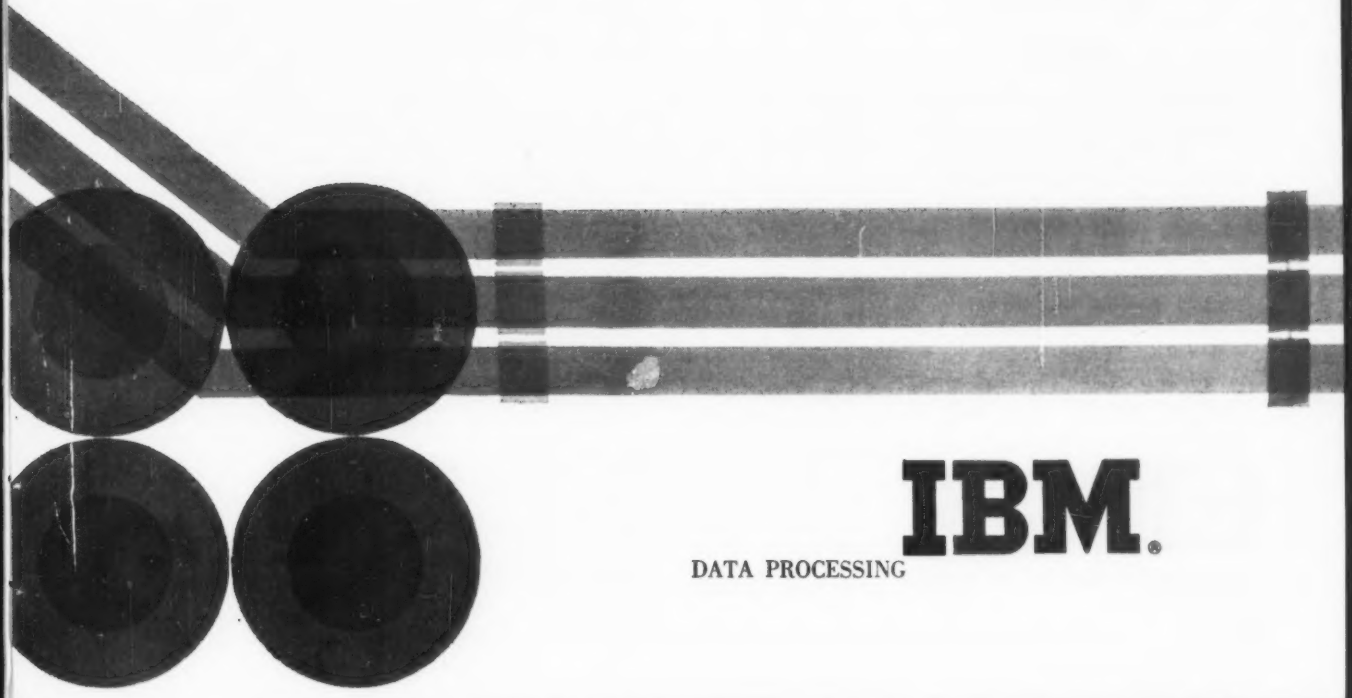
Since its introduction some five years ago, the IBM 650, in its dozens of configurations, has accumulated a wealth of petroleum experience that you can profitably use now. ■ Early users who first experienced the advantages of this "Electronic Workhorse" in technical calculations swiftly added accounting applications to its chores. As these daily chores increased, management developed a new awareness of the capabilities of electronic data processing. Many have since installed larger IBM systems. ■ For many petroleum companies, this versatile computer has become a pivotal installation—handling broad areas of calculation—creating more efficient use of facilities and manpower. These companies have found that the ability of the IBM 650 to deliver swift, accurate answers to knotty problems has led to many positive competitive advantages. ■ The IBM 650 is an oil man's computer—supported by years of petroleum industry and IBM experience—and ready to go to work for you. Like all IBM data processing equipment it, too, may be purchased or leased. Why not let your local IBM representative demonstrate how it can profit your company.



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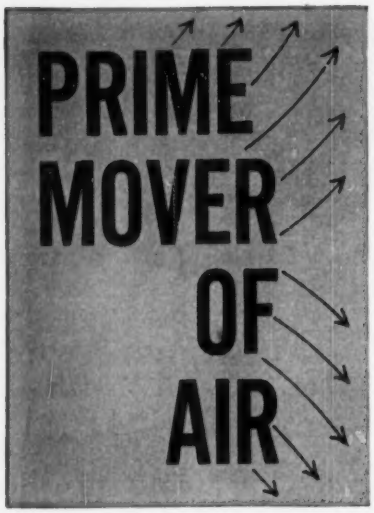

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Engineered Products Sold with *Service*

Building . . .

Alcochete, Portugal, and Orange, Texas. Construction of the plant in Portugal is underway and will be complete late this year. Expansion and modernization programs have been started or scheduled for Firestone plants at Akron, Memphis, Los Angeles, Des Moines, Pottstown, Penn., and Hamilton, Ont. Other U. S. facilities to be expanded include the Lake Charles, La., synthetic rubber plant and Pottstown plastic plant.

Allied Chemical Corp. has started design engineering work on a proposed polyethylene plant. An official site has not been revealed by the firm, but outsiders look for the unit to go up at Orange, Texas.

South Penn Oil Co.'s Rouseville, Penn., refinery plans to build a $1.25-million alkylation unit. A contract for the unit, which will produce high-octane blending materials for gasoline, has reportedly been let.

Texas Eastman Co.'s Longview, Texas, plant has increased its polyethylene capacity from 85 million pounds per year to 100 million. Oxo facilities recently completed will boost capacity for aldehydes to 125 million pounds annually.

Naphtachimie plans to double ethylene oxide capacity at its Lavera, France, facilities. The expansion will be complete by 1960. Scientific Design Co. will handle design and engineering for the project.

Warwick Wax Co. plans to install a $300,000 propane deasphalting unit at its Chanute, Kan., refinery. The company says the unit is the first move in a $1 million long-range expansion program.

Humble Oil & Refining Co. is reactivating its Baytown, Texas, butadiene plant, taken out of service last spring. Three of the four "mothballed" units are operating, and the fourth should be back on stream this summer.

Allied Chemical Corp. is reportedly planning an expansion of polyethylene facilities at the Tonawanda, N. Y., plant. The probable 50-percent capacity increase would bring to 30 million pounds per year the plant's output. The product will be used for extrusion into high-strength pipe.

Communist China is reportedly stepping up construction of ammonia and synthetic rubber plants. The Ministry of the Chemical Industry is said to be planning several small plants in major cities for sulfuric acid, butyl alcohol and several other chemicals.

Standard Oil Co. (Ind.) has completed a huge pipe still at its Whiting, Ind., plant, which will replace nine smaller units. The new 140,000-bpd unit will produce 64 percent of the refinery's 200,000-bpd total throughput. Engineered and built by Arthur G. McKee Co., the

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DIGITIZER

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With electronic null-balance accuracy, Swartwout's new Indicating-Digitizer directly converts transmitted data on any process variable into a digital code suitable for computation, telemetering, data logging or preparation of punched cards and tape. It indicates the variable, too, and may be operated in parallel with recorders and controllers.

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The entire instrument is packaged in a panel-mounting case that fits into a standard five-inch-square cutout. Calibration adjustments are readily accessible; the entire unit is of plug-in type construction for easy servicing.

Totally new, but thoroughly tried and tested, the Swartwout Digitizer is another advance in the new industrial era pioneered by Swartwout with fully electronic AutroniC Process Control.

For details on the Indicator-Digitizer, request Specification Sheet A-806. The Swartwout Co., 18511 Euclid Avenue, Cleveland 12, Ohio.

SWARTWOUT

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S.A. 1909

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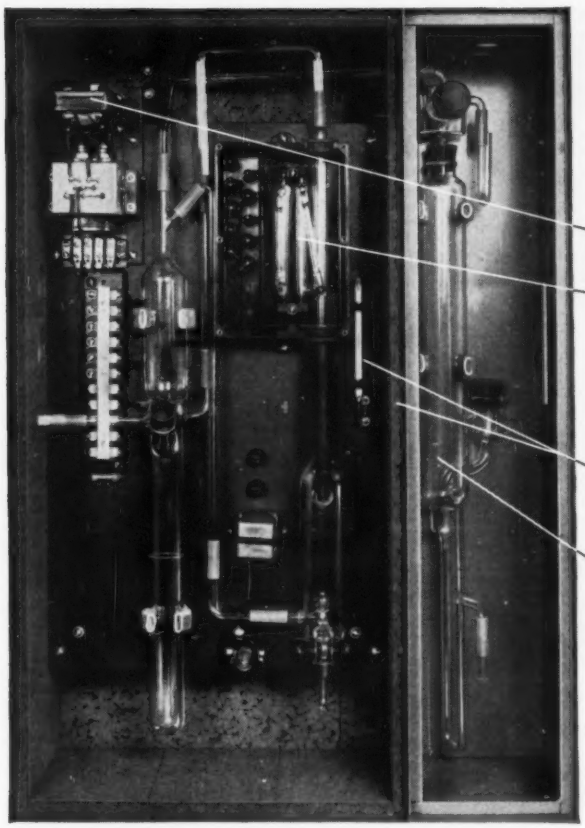
Gas Analysis a problem?

SOLVE IT PERMANENTLY WITH EQUIPMENT WHICH GIVES YOU THESE 7 ADVANTAGES



Thermal Conductivity Analyzer

In hundreds of plants, L&N's Thermal Conductivity Gas Analyzers are solving the problem of obtaining accurate, reproducible measurements of CO_2, SO_2, H_2 in N_2 and many other gases. Because they embody the benefits of thirty years' experience in process gas analysis applications, L&N Thermal Conductivity Analyzers . . . . .

1. Eliminate gas measurement upsets. A constant voltage regulator excludes a-c power variations.

2. Provide accurate measurements by using the unique L&N cell design which gives you vibration-free operation due to a rigid filament support . . . electrical stability by using a platinum filament . . . high corrosion resistance due to glass coating of the filament . . . and immunity to small flow variations because the cell is designed to utilize the gas diffusion principle.

3. Make reproducible measurements possible. Ambient temperature swings are eliminated by enclosing cell assemblies in an insulated case with thermostatically-controlled temperature.

4. Permit low maintenance and therefore minimum downtime as a result of the time-tested analyzer design including features such as flexible junctions, heavy glass construction, etc. Coal and asbestos filters remove mist and dust to assure cleanliness of the analyzer system.

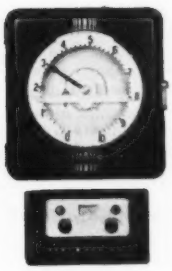
5. Match the inherent accuracy and sensitivity of null-balance Speedomax®G and H Recorders.

6. Permit selection of the particular type of control forms to fit the process. These include electric control, electro-pneumatic, and all-pneumatic controls—each designed to work with the Analyzer-Recorder system for maximum throughput.

7. Gives you undivided responsibility. The entire thermal conductivity system . . . sampling system, analyzer, recorder-controller . . . is designed, engineered and built by one organization with a nation-wide sales and service staff.

These "plus" features of L&N's Thermal Conductivity Gas Analyzers can help satisfy your demands for top quality products which lead to substantial savings. An eight-page booklet, Folder ND46-91(6) giving data on this equipment, is available by writing to Leeds & Northrup Company, 4923 Stenton Avenue, Phila. 44, Pa.

Speedomax H Series 60 Electric Control



Speedomax G Series 60 Electro-Pneumatic Control

Speedomax G Pneumatic Controller

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plant will continue to produce at 90 percent capacity when the vacuum section is shut down. It offers large capacity, wider range of fractionation and can produce asphalt directly. The new facility produces light, intermediate and heavy naphthas, furnace and heater oil, primary gas oil, vacuum tower bottoms, heavy vacuum gas oil and heavy materials. These products go from the still to other units for further processing without intermediate tankage.

Cyanamid of Canada, Ltd.'s Welland, Ont., plant plans to replace imported coal with natural gas for production of ammonia and ammonium nitrate, two of the plant's main products. The switch, expected to take about a year, will cost $5 million.

Union Carbide Corp. plans to construct a polyethylene plant at Melbourne, Australia, the output to add to the firm's affiliate, Union Carbide Australia, Ltd., which will build and operate the plant. Carbide's first Australian polyethylene venture is slated to go on stream early in 1961. The 15-million-pound-per-year plant will get ethylene from a new unit of Vacuum Oil Products, Ltd.

Shell Refining and Marketing Co., Ltd. has started up its new 1,000-ton-per-day Udex unit at Stanlow, England. The Ellesmere Port refinery unit produces an aviation gasoline blending component. Construction was started in 1957 and cost about $2.7 million.

Rummania has completed its Soviet-designed superphosfate fertilizer plant at Novodari. The plant currently produces 150,000 metric tons per year but will be increased to 250,000 metric tons during 1960.

Syria has signed a construction contract with Technoexport, a Czechoslovakian firm, to build a new government refinery near Homs. The plant, announced in the April, 1959, REFINER, will have a 750,000-ton-per-year capacity and will cost about $15 million. A smaller refinery, to be built by a private Syrian firm is said to be in the planning stage.

St. Paul Ammonia Products Co.'s Pine Bend, Minn., ammonia plant is on stream and producing more than 200 tons per day. Constructed and designed by The Lummus Co., the plant operates on natural gas most of the year—then switches to butane during the gas-scarce winter months.

Shell Chemical Co., Ltd. is building a 30,000-ton-per year polyolefin plant at Carrington, near Manchester, England. The new unit uses the Ziegler process.

Czechoslovakia is reportedly planning a synthetic rubber plant with a 30,000-metric-ton-per-year capacity. The plant would use Soviet processes and be completed sometime in 1963.

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FALK Steelflex SPACER COUPLINGS
save time and money in refinery operations

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Cut disconnect-reconnect time by as much as 50%

The FALK Spacer Coupling is specially designed for quick installation or removal *without disturbing the driving or driven unit*. This feature can save you up to 50% in disconnect-reconnect time when critical equipment—a process pump, for example—needs repair or replacement.

Here's another saving: with the FALK Spacer Coupling, you can quickly realign shafts *without the usual loss of operating temperature!*

And still another: you can remove or reinstall the FALK Spacer as a unit *without draining the lubricant.*

Because of its exclusive grid-groove Steelflex design, the FALK Space. can accommodate residual misalignment—parallel, angular, or (most important) *both*. Also, it provides torsional resiliency that cushions shock and vibration. Thus it saves wear-and-tear on your connected equipment.

To prove these claims and enjoy these savings, install a FALK Spacer on one application—and see for yourself. Consult your FALK Representative or Authorized Distributor.

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MANUFACTURERS OF QUALITY GEAR DRIVES AND FLEXIBLE SHAFT COUPLINGS
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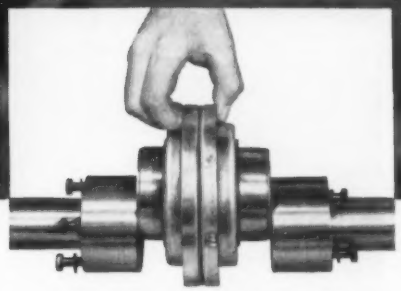
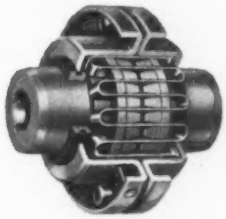


EASY AND QUICK TO INSTALL, DISCONNECT OR RECONNECT

First, mount shaft hubs to allow proper distance between hubs; then, align driving and driven units.

Second, compress Spacer to fit space between hubs and tighten cap screws to pull spacer hubs into the registered fit.

To disconnect, reverse the second step. No draining of lubricant necessary.

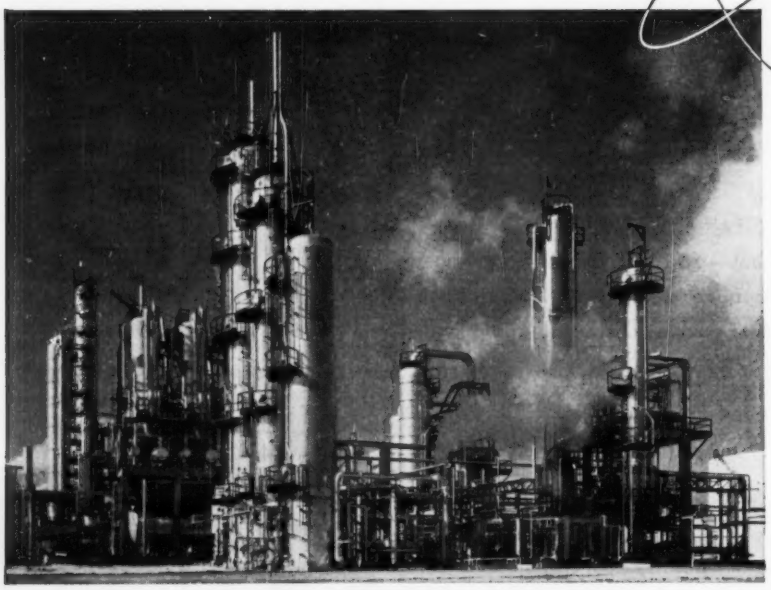


The heart of the FALK Spacer ...the basic Type F Steelflex

Write for Service Manual 4838

FALK
...a good name in industry

Photos by Robert Yarnall Richie



Designed, engineered and constructed by The Lummus Company, this giant petrochemical complex at Lake Charles, La., has three separate control rooms. The compressor and boiler unit is controlled by 38 Microsen control loops. 141 other loops measure variables to control ethylene processing, and 75 more control the ethylene oxide-glycol unit. Kybernetes data read-out equipment is integrated with Microsen instruments in one of the control rooms.

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Over 250 Microsen® loops automate processes at Petroleum Chemicals, Inc. and Calcasieu Chemical Corp.

Microsen Electronic Process Instrumentation measures and controls temperature, pressure, flow, and liquid level in this new $80,000,000 installation. Microsen, the DC control system pioneered by Manning, Maxwell & Moore, Inc., was selected for quality of control and ease of installation.

Standard Microsen instruments are used in cascading. By adding ratio amplification in the output of master Controllers, special variable cascade units are created.

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If a process upset occurs, the amplifier increases output in the indicated direction to correct the deviation. Amplifier output then decays to zero. Decay time is continuously adjustable within a range of .05 to 5.0 seconds.

Field wiring from Transmitters and Valve Positioners is carried in explosion-proof conduit which terminates in ducts at the rear of the panels in each control room. Wiring from ducts to panel instruments is covered with flexible rubber.

Microsen Electronic Process Controls assure permanent savings. They instantly transmit accurate measurements over long distances – assure process stability and efficiency. The DC signal (1.0 to 5.0 ma) is compatible with practically all data handling, telemetering and computing systems, and with process stream analyzers being developed. Microsen design flexibility anticipates ever-changing needs in process control.

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Be Sure You Write What You Mean!

If your writing is ever misinterpreted or ignored, then you have a communications problem. Here are some points which will enable you to improve your letter and report writing

B. J. Wachter
National Aluminate Corporation, Chicago

WE SAW an accident recently where a small foreign car crashed into the rear of a trailer truck. The truck driver, looking for all the world like a truck driver, approached the driver of the foreign car, a mild mannered man. The preliminary exchange was brief and well punctuated.

Truck Driver: "What are you going to do about this?"

Mild Mannered Man: "I think we can settle it amicably . . . ."

Without another word the truck driver swung. Apparently he took offense at the word "amicably" not knowing (or caring for that matter) what it meant. He probably didn't realize he was taking offense. He was just plain mad.

Since this was a face-to-face situation the misunderstanding was eventually cleared up. (Ultimately, amicably). But it made us stop and think. If one vocal word could cause such a ruckus, how did the hundred thousand odd words we wrote in the normal course of events last year fare? All of these words, unalterably put into type, conceivably could cause mayhem. We don't think they did though. Very likely most of the words were lost irrevocably. They "withered on the line," so to speak, without being plucked by appreciative readers.

Whenever our written words are misinterpreted or just ignored we have a problem in communication. This is a serious problem since we have definite responsibilities in keeping the word-mill running efficiently. We have to exchange information with our contemporaries and associates on everything from aardvarks to zirconium, and we have to write it down to make sure they (and we) get it right. Let's stop and think about this for a while.

Between The Lines. When we stop to think about it we realize that we can't write writing. Writing is a way of communicating and the written word is just a one dimensional idea. It only becomes full bodied when it expresses what we mean and is properly interpreted by the reader.

In this sense we might compare the written word to a crocodile egg. To illustrate: Let's consider that the mature female crocodile lays 100,000 eggs every year with only 100 being fertilized. Similarly, we might write 100,000 words every year and only have a small fraction of them reach full maturity by fulfilling their intended purpose.

The crocodile situation is of concern only to crocodiles. However, there should be a human concern too—about nurturing embryo ideas through effective writing. This concern leads us to consider what is involved in written communication. We find that writing (like Gaul) is divided into 3 parts. It consists of:

1. The writer
2. The written word
3. The reader

In studying the relationship between these parts certain gaps become apparent. These gaps occur between the lines, thus our ideas may either lose something or be distorted in translation. Let's consider briefly what goes on between the lines.

You and Your Words. Psychiatrists, in treating mental patients, often use a word association test. This involves reading a list of words and asking the patient to respond to each word with another one. A patient may respond to the word "red," for example, with: "hair," "anger" or even "communism." The pattern of responses sometimes gives

Putting words together is a personal process. However, these combinations can be as unappealing as cold gravy or as pleasantly provocative as a well-turned ankle

an indication of an underlying emotional problem.

The word association test illustrates that words are associated with feelings or emotions. (It also illustrates that a word is a word is a word is a word.) This is true for normal people as well as mental patients. Therefore, even though we understand the meaning of a word, we nevertheless tend to associate it with personal experiences. Thus, many times these word associations come out in our writing. In these cases, our writing does not represent our true intent, but rather, our automatic emotional response in a given situation. Each of us can break this word association pattern by carefully differentiating between facts and feelings.

Summing up: Effective writing requires conscious effort. Thinking is the pause that expresses.

The World of Words. Don Marquis wrote the following lines which apply, to a certain extent, to all of us.

"I do not work in verse or prose,
I merely lay out words in rows;
The household words that Webster penned,
I merely lay them end to end."

Although verbal "brick-laying" is sometimes acceptable, when words are used as building blocks the final result depends on the architect. The finest words Webster has to offer are meaningless unless they are properly built into our writing.

We have certain guides for "building" words. Grammar affords a very broad blueprint. Form and style have also developed some standardization through usage. There are no specific rules, however, which dictate how to write. If there were, we might end up with "word communism" and identical word structures, like universally identical buildings, would result.

Summing up: Putting words together in writing is an individual and personal process. Word combinations can be as unappealing as cold gravy or as pleasantly provocative as a well-turned ankle.

Interest the Reader. A reader, by natural disposition, is lazy. His voluntary status as a reader is strongly dependent on one motive: self-interest. This may take the form of obligation, intellectual or emotional satisfaction or just plain curiosity. The reader likes his writing short and simple so he can decide quickly whether or not it involves his self-interest.

It is important that these basic interests be taken into consideration in writing. As writers, however, we must do more than appeal to the reader's interest in saving time. We must use empathy—put ourselves in the reader's shoes—to present our thoughts in a way he is most likely to accept them.

Clarence Darrow, in speaking to a group of English professors, once said, "Even if you do learn to speak correct English, who are you going to talk it to?" This question also applies to writing. The most profound writing will never be fully appreciated unless it is read, understood, and accepted by the reader. Spanning the gap between the written word and the reader is a challenging job in creative bridge building.

Summing up: Writing involves a dynamic interaction between writer and reader. It requires all of the ingenuity of the schoolboy's letter home for money.

Three Questions. After recognizing that writing is a personal process requiring effort and understanding of the reader, where do we go from there? The professor of a short story course when asked a similar question, "How do I begin writing a short story?" replied, "Drop this course, go home, and start writing." In short, the answer is practice—we need to practice to improve our writing. In fact, each time we write, we might ask ourselves 3 questions:

1. What do I want to say?
2. Does my writing say it in the clearest possible way?
3. Are my thoughts presented in the form most acceptable to my readers?

If we can answer these questions to our own satisfaction we are "on our way" in making our writing more effective. But maybe now we need a few checks for objectivity to be sure that the individuality of our writing does not get out of hand. Let's, therefore, recognize certain extremes in individuality which we will caricature as: the Dictator, the Educator, the Hourglass and the Dumptruck.

The Dictator. We have difficulty in looking between the lines of the Dictator's writing since there is no between. His written communication is blunt and to the point; it is black on black and we dare you to find shades of grey. This has its good features since it leaves no gaps between writer and writing, but it is not true communication since it meets a Waterloo in the reader.

This type of writing is effective, however, in direct proportion to the obligatory nature of the reading. It is good only insofar as the writer's ideas are infallible, since the written idea will never require reader interpretation. On the other hand, it will very likely suffer because of reader resentment.

In reply to an inquiry such as:

"I am searching for a new plant site in a warm climate with good fuel readily available and good labor supply. Where would you suggest I look?"

A typical response from the Dictator writer would be direct and to the point: "Go to the devil."

The Educator. The Educator writes tangentially. His fetish is completeness. He begins at the beginning and works methodically from there, getting off on frequent tangents which in due course have little relationship to the original issue. The Educator is an effective communicator, but the prime requisite for his reader is patience.

In response to the same inquiry given above, the Educator's reply would run something like this.

> "The first plant sites were always located near accessible water supplies. This was because water was the earliest source of transportation. Some difficulty was experienced originally in this country when Indians repeatedly attacked plant sites. Some of the tribes of Indians which were common during the early days of our country's development were the Iroquois, the Sioux . . . etc."

Ultimately, he would formulate a good answer to this inquiry, but not until such things as the customs of the early Indians, and the effect of glaciers in cutting out waterways, were fully explored.

The Hourglass. The word "urgency" is not to be found in the Hourglass writer's vocabulary. The sands of time run slowly through the constricted area of his brain. Ideas are like individual grains of sand which flow constantly, but very slowly. For example, replying to the same inquiry, the Hourglass writer might say:

"What type of plant are you putting up?"

After the reply is received giving all the partinent facts on the type of raw materials, processes, and finished products involved, the Hourglass writer is likely to reply:

"What type of fuel were you interested in?"

Presumably, after this point has been cleared up, a clarification of the type of labor supply would be requested.

The Dumptruck. The Dumptruck writer is prone to unload all of his ideas on a given subject at the slightest provocation, a process quite similar to free association. The method does not necessarily involve any natural or logical relationships between ideas. His writing is like a brush fire which needs only a spark to start.

Many useful, stimulating, and even ingenious ideas can be obtained from the writings of the "Dumptruck." The ideas and information, however, must first be ferreted out and pieced together from the verbal rubble. The "Dumptruck" writer would respond to the question in this manner:

> "The selection of plant sites is a real problem. Back in 1936 while I was working for Consolidated Steel we were putting up a branch plant. I remember that our biggest headache was transportation of materials. And then our processes were pretty unique so we had to have specially machined installations. This is something you might consider in your early planning stages. Get your equipment set up right. It will save a lot of trouble later, etc."

Package Your Ideas. As direct consumers we would find it very awkward if we had to buy steel by the ton, wheat by the bushel, or milk by the cow. Similarly, the average person is unable to read the *Congressional Record* daily. In order to make commodities and information convenient for direct use they must be processed, and in taking them to market, an appropriate "package" is needed. This holds true for our everyday writing—it must be processed with thought and packaged in idea units of the size needed for direct consumption.

We might consider good written communication to be like playing "catch" with a ball. The writing should be solid and rounded without loopholes or sharp edges. The size of the ball (the written package) should make handling easy. The receiver's attention must be attracted so that the ball will be caught and the writer must be ready to catch the ball in return.

Conclusion. A problem in written communication is that often our words take on a character entirely unrelated to their intended meaning. The meaning of these wayward words diverges in the gaps between writer and writing, or writing and reader. We have to look between the lines, therefore, to determine whether something is "lost in translation."

In thinking about written communication we come to 3 conclusions:

1. Effective writing requires conscious effort

2. Putting words together is an individual and personal process.

3. Writing involves a dynamic interaction between writer and reader.

In evaluating our writing we asked ourselves these questions.

1. What do I want to say?

2. Does my writing say it clearly?

3. Are my thoughts presented in a form most acceptable to my reader?

We can compare our writing in terms of the extreme styles used by the: Dictator, Educator, Hourglass and Dumptruck.

Finally, we must package writing in a form acceptable to the reader. Rounding out this package cuts down friction and enables our writing to "roll" and acquire momentum. Written communication is like a ball. Here, catch! ##

About the Author

B. J. Wachter is a staff engineer with National Aluminate Corp., Chicago, where he develops and promotes de-scaling chemicals and distributor products. With Nalco for seven years, he has worked on technical service of water treatment chemicals, particularly for boiler feed use. Before assuming his present duties, he was manager of technical service, marine boiler feedwater. Wachter has a B.A. degree in chemistry from Pennsylvania State University, and was a graduate research assistant at the University of Pittsburgh, 1950-51. He studied creative writing and marketing at Mexico City College and at Northwestern and Chicago Universities.

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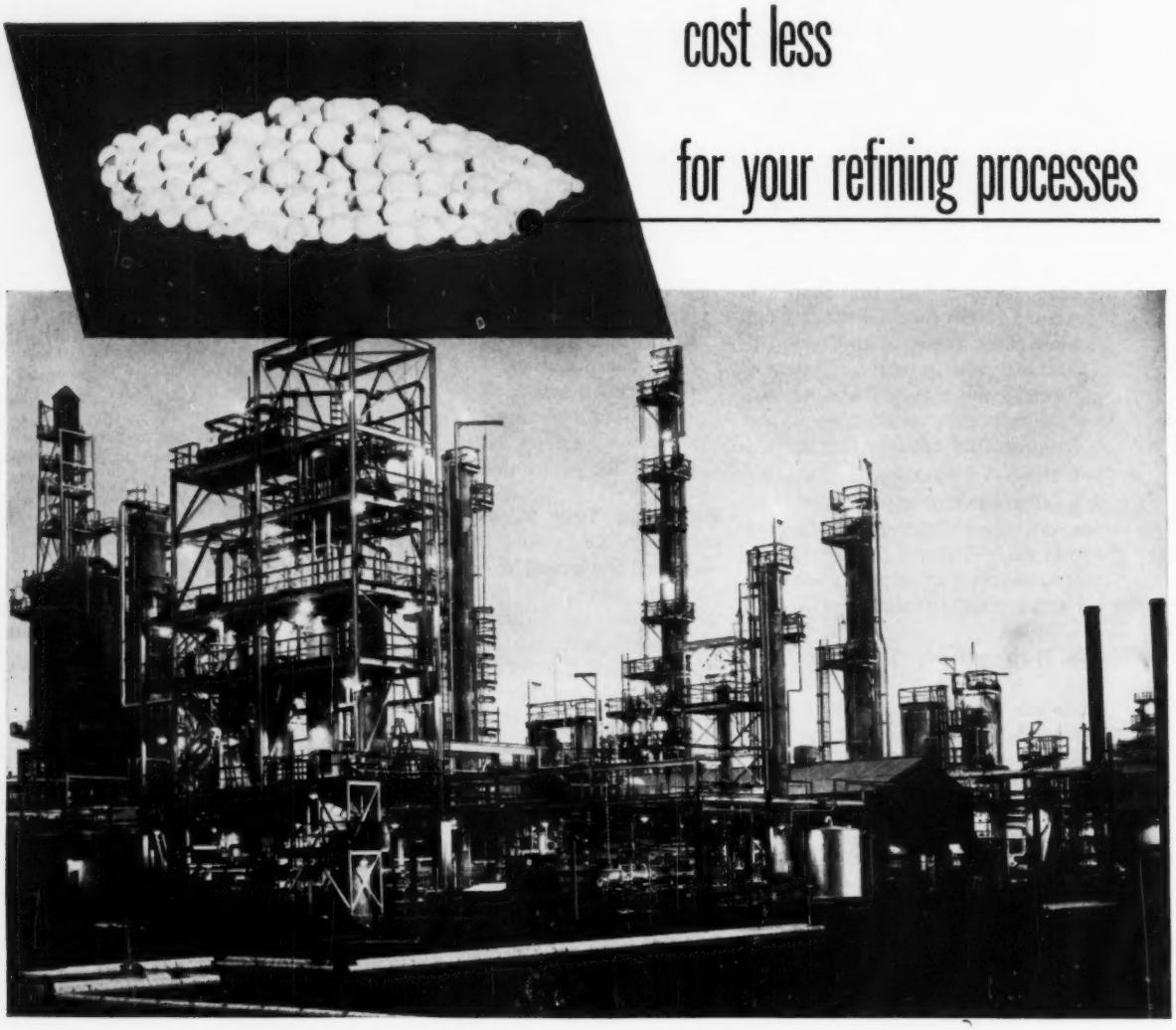

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Speak Up When Disaster Strikes

In times of crisis, your organization's reputation with employes and community is at stake. Here's how management can keep a plant disaster from becoming a public relations disaster

Henry H. Hunter
Olin Mathieson Chemical Corp.
New York City

A RECENTLY PUBLISHED book titled, "The Diary of a Strike," states, "The best of all possible moments to achieve insight into the life of a human being is during a fundamental crisis, when he is faced with grave decisions which can mean ruin and despair or success and happiness."

General S. L. A. Marshall points to the same conclusion in his studies of warfare—that the true nature of a man emerges only in times of emergency, stress and crisis.

In the same way that a personal crisis makes or breaks a human being, a public relations crisis becomes the "moment of truth" for a corporation. And by far the most critical and dangerous public relations crisis that a company can face is the plant disaster—the explosion, fire or other accident that causes death, injury and destruction.

That Sudden Change. Consider what happens to a company when disaster strikes. In one moment, it's peaceful routine and business as usual. The company is trying to conduct itself in a way that deserves the respect of customers, employes, stockholders and neighbors. It conforms to certain public relations policies, all designed to demonstrate the soundness and maturity of its management, the quality of its products, its advantages as a place of employment, and its concern for the welfare and security of its employes.

One moment later disaster strikes. And, as Artemus Ward once said: "The fack can't be no longer disgised that a Krysis is onto us." Within seconds, all the progress ever made in earning and deserving the good will of its publics is up for grabs. Every act and statement designed to win the confidence of employes, customers and the community is on the line for possible eclipse.

It Can Happen to You. Now, a disaster can strike any company. No one is immune. Even with the remarkable safety record of the chemical industry, not a single chemical company can say "it can't happen here."

Then why do many companies fall down under the pressure of an emergency? Why is it that so many companies—large or small, with well-trained public relations personnel or without—handle themselves so badly when the chips are down?

The reasons, in my opinion, are three:

1. They Aren't Prepared. They have no pre-arranged policy to guide them in an emergency. This is a tragic omission, especially when the layman comes to grips with the public relations problems a disaster creates. Many good business executives, under the pressures of a public relations emergency, will bounce in the wrong direction every time. The reason is that every instinct of a person inexperienced in public relations

causes him to do exactly what he must not do.

2. Panic. The only way to eliminate most of the mistakes that panic can lead to is to provide emergency guidance—in advance—and in such detail that the decisions to be made under stress are kept to a minimum.

3. Lack of Executive Understanding. This involves the difficulty many executives have in understanding the duties, responsibilities and requirements of the press. When reporters and photographers arrive on the scene of a major disaster—and arrive they will—it's easy to view them as a hostile group who can do a great deal of harm. Harm they can do—but hostile they are not. At least, not until you earn and deserve hostility.

The plant official is quick to recognize that between himself and the press there is a conflict of interest and, in sensing this, he is usually right. But he often fails to realize that there is also a way to accommodate his interests with theirs and that in this accommodation, lies the only real solution to his dilemma.

Western civilization treasures freedom of choice and the philosophical conception of free will. The hardest thing in the world to do is to tell a man that in a given situation he has no freedom of choice. Yet—and this may be a blissfully pig-headed statement—where handling the press in a disaster is concerned, there is no freedom of choice. One road leads straight to hell and the other to purgatory. And when your plant goes up and people are killed, journalistic purgatory can be a relative heaven.

It's true that some companies handle themselves so skillfully in a crisis that they come out with an added measure of sympathy and respect. But what we are mainly concerned with is avoiding those common mistakes that can haunt a company for years.

Case History. One summer day eleven years ago, a little before the lunch hour, a fire broke out in the main plant of a very well known industrial corporation. By 12:30 the fire was raging out of control. All the fire fighting apparatus of a large city was arriving on the scene and, with it, the inevitable corps of reporters and photographers from newspapers, wire services, radio and television.

Guards at the plant gates received these orders from management shortly after the fire began: "Let the firemen in, keep the newspapers out."

During the afternoon the zealous guards at the plant gates chalked up these significant public relations triumphs: One reporter was hit in the nose; a photographer's camera was deliberately smashed; another reporter was ejected from the grounds after he had sneaked in and was caught interviewing employes.

Still Feeling Repercussion. It's no surprise that these three newsmen's attitude toward the company became unenthusiastic. It's no surprise, either—at least to any one in public relations—what a tremendous price the company paid for a few hours of sheer stupidity. Twice since then the company has been the victim of large and nationally critical strikes that have made newspaper headlines coast to coast. In every case, newspaper coverage of these was less sympathetic toward the company point of view than it might have been.

News stories the company wanted to see appear—marginal news value stories on local developments that were designed to insure a good labor pool, or new product stories designed to help build customers—either wouldn't run at all, or if their news value was undeniable, were given secondary or critical treatment.

And further, in the absence of a favorable press, it is hard to imagine that the job would have been any easier had the company had to go to the community for favors such as industrial rezoning or requesting a lower tax assessment.

Still and all, maybe all of this would have been worth while if the company had accomplished something of major consequence by its original decision of trying to shield the disaster from the press. But just what was accomplished?

Lengthy Treatment. Newsmen buttonholed firemen and employes leaving the scene and pieced together stories from often exaggerated and distorted facts. The mystery surrounding the fire kept it in the headlines for weeks, long after it would have made news if the true facts had been known. And in the absence of any official information, every unfounded rumor was given prominent treatment.

The story the company didn't want to run ran anyway. The action taken by the company accomplished nothing. On the negative side, however, the company accomplished a public relations debacle that turned out to be a greater disaster than the fire itself.

Whose fault was it? There is really not much doubt it was the fault of management. But if you asked management itself whose fault it was, you'd have gotten a different answer. In their eyes, the villains in the piece were the newspapermen. This isn't unusual in such a situation. When the corporate walls come tumbling down as the result of bad press coverage, the culprit is often a specific newspaperman or that generic villain, "irresponsible reporting."

This comes up so many times that it's worth considering—what is irresponsible reporting?

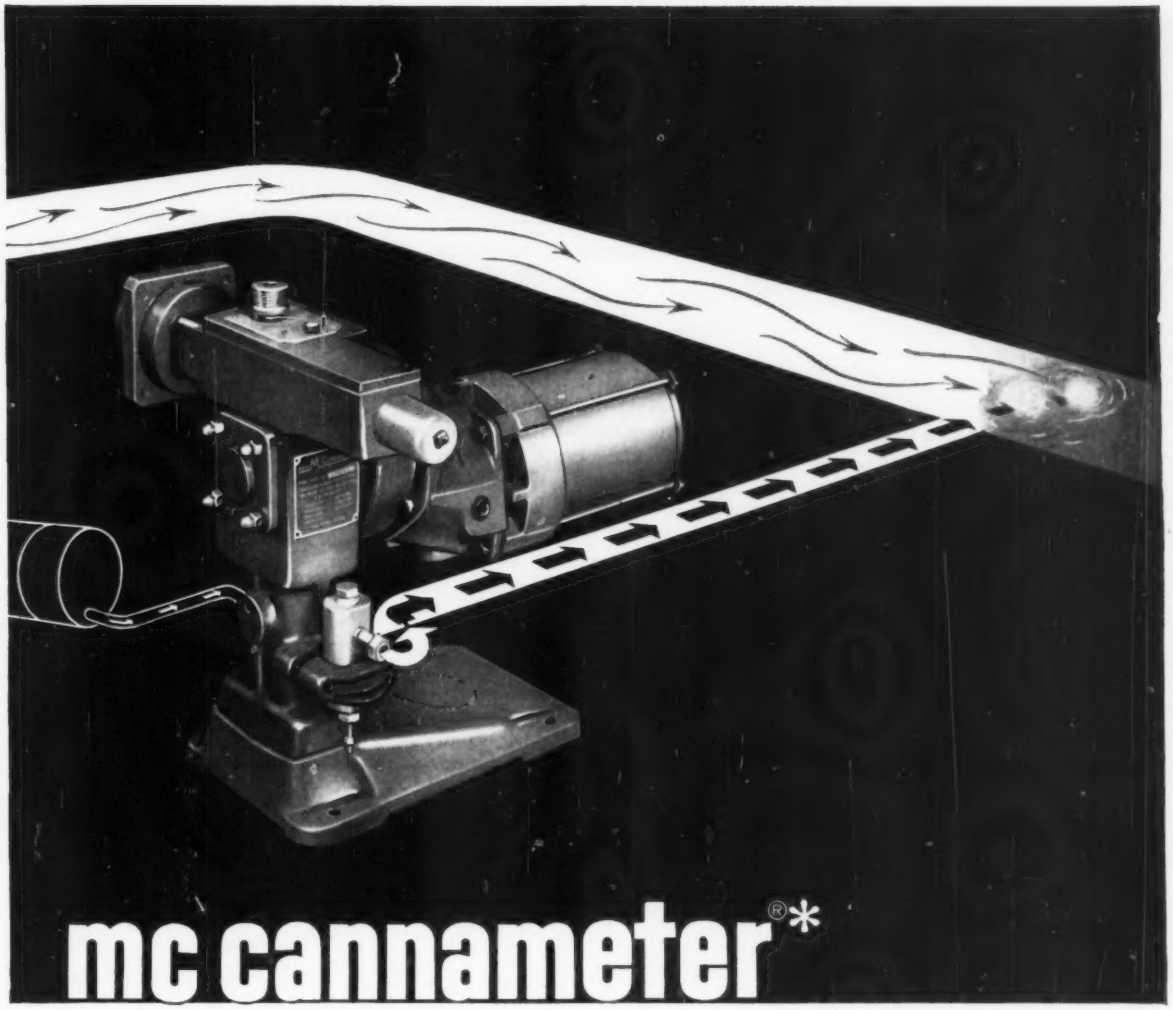
Two questions must be asked. Whose irresponsibility and whose reporting?

What Is News? A story that seems irresponsible to a company executive may well meet the highest standards of the country's best run city desk, because as you know, the criteria are different. When Adolph Ochs adopted the slogan for the *New York Times*, "All the News That's Fit to Print," he reserved for the Times the right to measure fitness.

If a newspaper or magazine carries an honest story about a plant disaster that reflects badly upon the company, this is a legitimate cause of concern to company management. But it is not the prime concern of a newspaper or its reporters. Their concern is to tell the story as best they can with all the facts that are available.

This brings us to the second question about "irresponsible reporting"—whose reporting?

Reporters Need Facts. When a reporter gets an assignment, he is expected to return with a story. This is his job. It is his instinct to seek the most authoritative source available for the facts he needs. In the situation of the fire which we discussed before, the most authoritative source was, of course, company management. But management would not



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talk to the reporters, so there was only one course open to them. They had to get a story and they had to get it fast. So they did what you or I would have done. They talked to the people who had seen what happened. These were mostly employes, many of them shocked by narrow escapes, unnerved by the frenzy and confusion, and prone to exaggerate both the damage and the danger.

From the company point of view, they were the worst possible sources. Yet it was management itself that forced reporters to rely on these secondary sources.

Now, officials of this company were men of intelligence, ability and sound judgment. Their decisions during the fire were made because they honestly considered they were in the best interest of the company. The fact that they were so wrong in everything they did was due simply to their ignorance about news and the people who gather it.

Poor Communications. The failure of company officials to establish a sound working relationship between themselves and the press underlies almost every instance of botching the public relations aspects of a plant disaster.

The prime reason for this is the happy hope that by refusing to meet with the press, we can keep the story of our misfortune out of the newspapers. The fact is, of course, we can't. As soon as an event becomes a matter of concern and interest to a community, the newspaper will do everything in its power to get the story. This it regards not only as a right but a duty.

No one likes bad news, particularly those most intimately touched by it. But the people of any community are interested in it and the newspaper's prime allegiance is to the community and its readers.

The reporter who phones and asks for our earnings figures in advance will respect our right not to divulge them. If he hears a rumor about a new product or process, he can sympathize with our efforts to keep it secret. But if disaster hits a plant and touches the life of a community, he will dig deep for all the facts he can get. Inevitably and irrevocably he will publish the story. And he will work at a story for days, if necessary, to get all the facts his editor wants.

Story Will Run. If we can accept this as a basic premise, we take a giant step toward handling the press properly. Once we accept the fact that the story will run, we can turn our attention to what it will say. And it is here, and only here, that management can affect the result. While no one, by pressure or persuasion, can keep the story out, intelligent press relations can earn the respect, understanding and even sympathy of the press at a time when it counts.

In the days when the airline industry practiced Model T public relations, they tried to keep all stories of plane crashes out of the papers. When a plane did crash, squads of men were rushed to the scene to keep the prying eyes of the press at a distance. Sometimes, they even splashed buckets of paint over the name of the airline to keep it from showing in news photos. They refused to divulge the names of the casualties. Their answer to every question from the press: A terse "no comment."

Then one day, so the story goes, a public relations man was hired from another industry to fill a minor post for a major airline at a southern airport. In his first evening on the job, his new employer dropped an airplane right in the middle of the runway. Before he had been indoctrinated with his employer's principles of press relations, he had a job to do. He did it by instinct.

PR In Action. He first phoned every newspaper, wire service and radio station in the city. He introduced himself, told them what had happened, and where at the airport he could be found. He obtained a copy of the passenger list, found out how long it would take to notify the next of kin, had the list reproduced and marked it for release the next morning. He typed a statement saying that the cause of the crash was unknown but that an investigation would begin immediately.

All this material he gave to the press when they arrived. He also did everything else he could to be helpful.

The next morning, the crash made headlines from coast to coast. His bosses were furious and they hauled him to headquarters to be fired. But first they gave him a hearing.

At the meeting, he compared the newspaper coverage of this crash with one six months before. The crash he handled made banner headlines in the morning papers. That evening, it moved back to Page 3. The next morning, the papers carried nothing.

Out and Over. The crash that had happened previously made lively news for nearly a week while reporters probed and dug for additional facts. As each new fact was brought to light, it made another headline. The reason the second crash was covered in one day is that in one day the papers had the entire story. When there was nothing more to say, and they closed the books.

"Which would you prefer," he asked them at this rather memorable meeting, "to remind people of an accident in every edition for a week or to get the story out and get it over?"

From this day on, the public relations policies of airlines, railroads and others who must live under the constant threat of banner-headline tragedy, have become among the most enlightened of all industries.

Rules for Disaster. If all the experiences that any of us have had in the public relations handling of a disaster can point to a valid set of rules and principles, then maybe our collective mistakes have been worthwhile.

I believe there is such a set of principles and, in summary, here they are:

1. Make one person responsible for handling the press in times of an emergency. Assign him this responsibility in advance—not after the disaster happens. Make this his only responsibility in a disaster situation. And choose a man who understands at least the fundamentals of good press relations.

2. Anticipate the questions the press will ask and begin to get the answers immediately. Basically they will want to know: What happened and what caused it; name, address, age and job of any casualties. Of course, this should not be given until families are notified. Also the nature and cost of the damage, and whatever plans you have for rebuilding and resuming operations if they were interrupted.

3. Inform all news media as quickly as possible. If the accident is a minor one, they will probably be content to take the information over the phone. If major, they may

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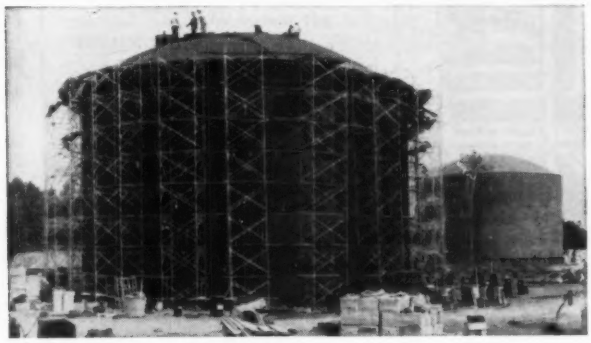

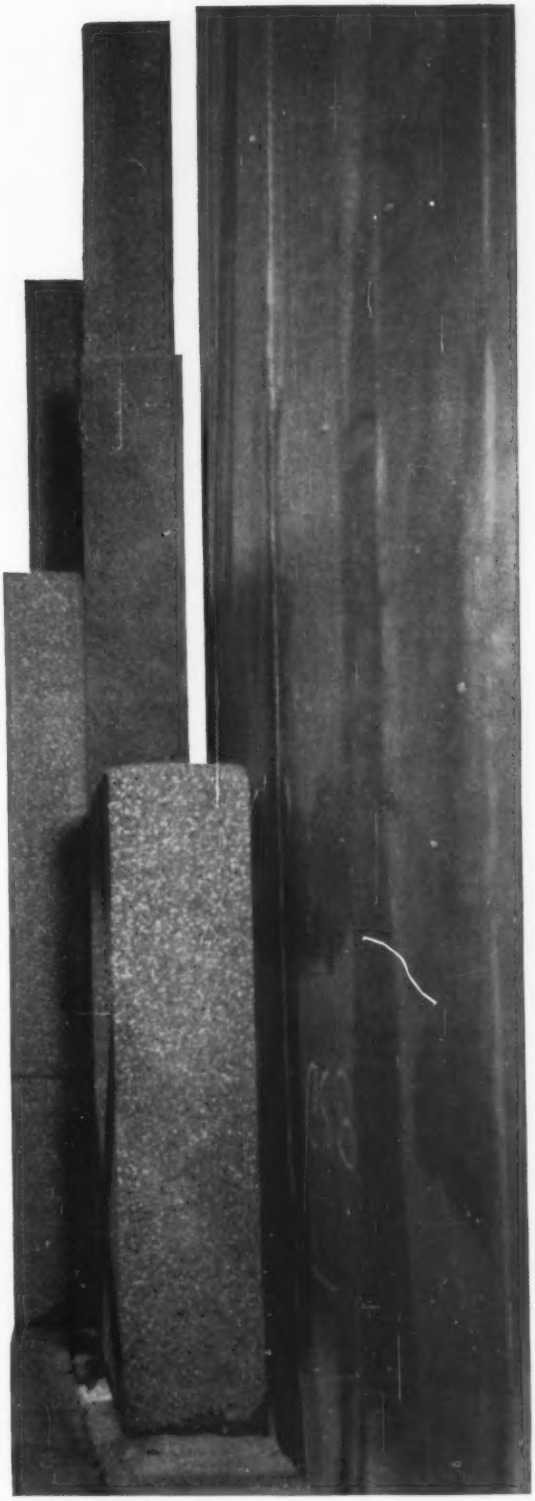

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want to cover it in person. If they do, tell them that you will do your best to answer their questions, give them the name of the man in charge of assisting them and ask them to contact him when they arrive at the plant.

4. Set aside a room to serve as press headquarters. Choose one that has as many phones as possible and ask the switchboard to expedite any calls on these phones.

5. Make whatever arrangements with plant guards and security people to get the press into the plant and make sure they are handled courteously.

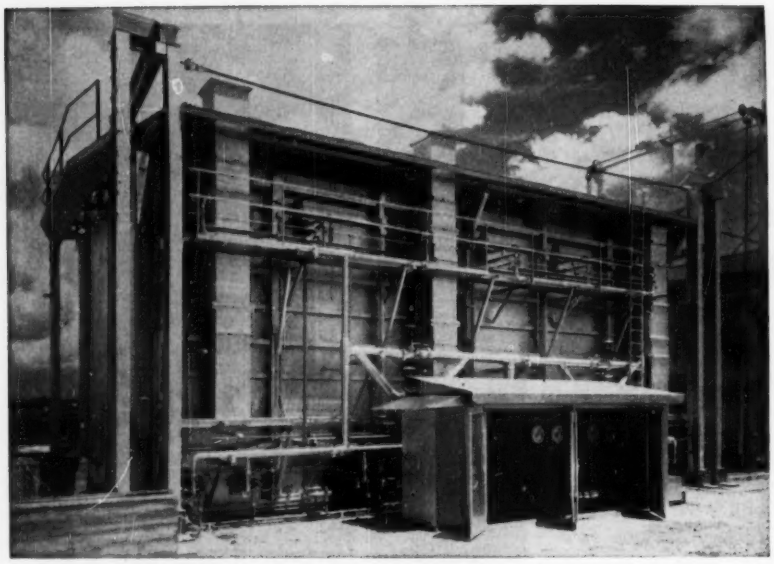
In short, establish the company as the source for the information they used and get them the facts they want as quickly as possible.

And as the pressure mounts, remember that the spotlight of public attention is focused upon you. That public opinion, always a fickle mistress, will be poised to move with you or against you—according to how you act under crisis.

Originally presented before the American Chemical Society, April 8, 1959, Boston.

About the Author

Henry Hunter is a director of public relations for Olin Mathieson Chemical Corp., New York. He attended Williams College from 1941-45, and after wartime military service attended the University of Missouri School of Journalism. During the years 1949-51 he was successively assistant city editor, Champaign, Ill., *News Gazette;* assistant managing editor, Irving Cloud Publishing Co., and assistant publicity director, Ross Roy, Inc., Detroit. From 1951-54 he was assistant public relations director, Grant Advertising, New York. Hunter then joined Olin Industries to manage product publicity. When the company merged, he became Olin Mathieson Chemical's publicity manager. In 1955 he was named assistant director, public relations, and attained his present post in 1957.



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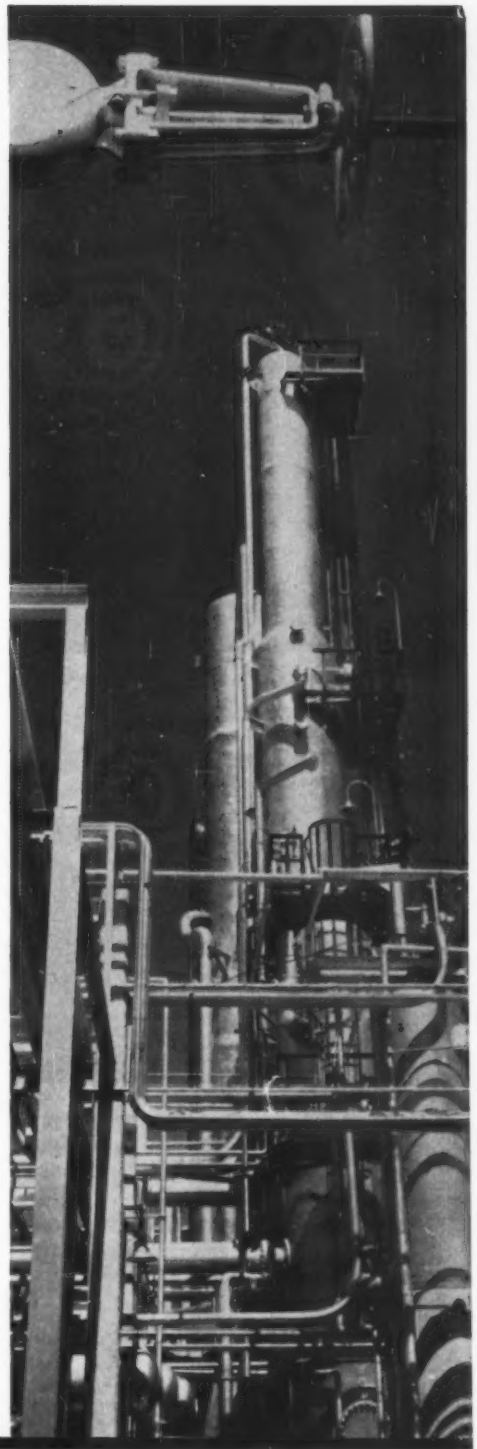

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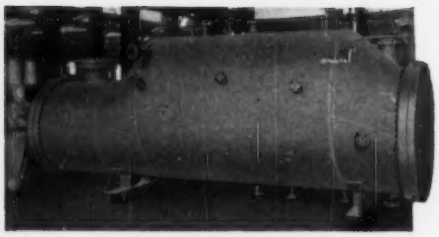
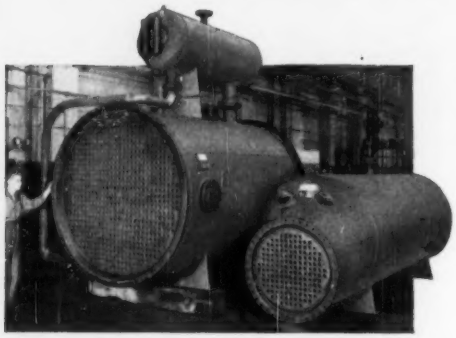
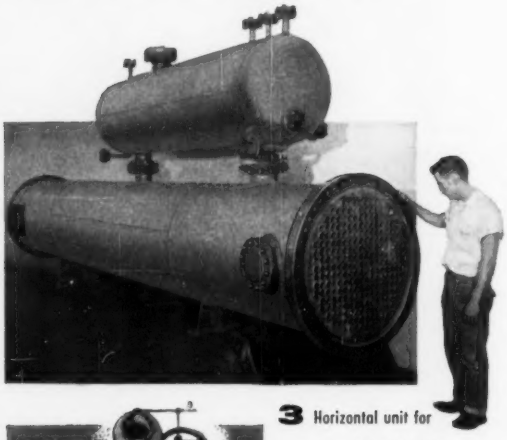


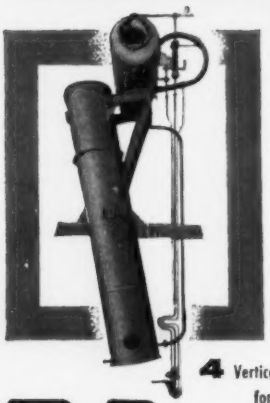
1 A nitric acid plant installed this unit. It has a built-in platinum catalyst chamber.



2 A methanol plant operates these horizontal type units.



3 Horizontal unit for a nitric acid plant.



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THE ENGINEERING profession has matured into a dynamic force that has raised the American standard of living to levels that only a short time ago seemed fantastic. Engineers have turned the atom into a worker for peaceful means and have made machines that store vast quantities of data. In short, we seem to have conquered space—yet, we have not matched this apparent success in the area of storage and retrieval of information. Let us define this process by calling it "Documentation."

What Is Documentation? Documentation is a new concept that is a way to get data by selecting words freely. And this is done in such a way that without prior knowledge of existing information, one can retrieve this information easily and quickly.

Generally speaking, we record information because it contains data on the success or failure of a given measure of work. This is done so we can use it in the future, should the occasion arise. But, selection and retrieving techniques are so antiquated that efficiency in retrieving information is low—perhaps as low as 10 percent.

The high levels of technical developments are evidence of engineering progress—yet our supporting techniques—our filing systems, documentation system or whatever you wish to call them, do not lend adequate support to the total engineering effort. How much better design could we have done or what better methods could we have used had the right information been made available? What duplication of engineering effort is now plaguing your own organization? How many times a week do you invent the wheel?

Recognizing this problem, a group in the central Engineering department of du Pont has been studying documentation. We have investigated practices and performance both in du Pont and elsewhere, including numerous other industrial, governmental, educational, and consulting organizations. We concluded that developments now occurring in the documentation field have potential for meeting our needs. Accordingly, we began active work on improving documentation in the Engineering department.

Engineering Department Functions. The major functions of the Engineering department are:

1. To translate economically the results of research and development (by the company's industrial departments) into satisfactorily safe and profitable operating facilities (for industrial departments).

2. To assist those departments in improving operations of existing facilities by providing specialized engineering, consulting and study assistance.

Hence, du Pont does not employ contractors to design and build plants, although frequent use is made of subcontractors. While the Engineering department also performs basic engineering research, it does not normally engage in product development or product engineering.

In carrying out its duties, the Engineering department has originated about 4 million documents with some degree of lasting value. This includes about 1.25 million drawings of various types, 10,000 technical reports, and many other types of documents common to such engineering operations.

Our objectives were to evaluate the department's documentation practices and performance, to define the problems involved in documentation and to estimate the practicability of substantially improving documentation.

PRESENT METHODS

The present system of documentation within the Engineering department follows traditional lines of information handling: classifications and alphabetical indexes. However, these conventional principles failed to solve the basic problems in documentation.

Each improvement in one area was invariably accompanied by a

* Present address: ITT Laboratories, Nutley, N. J.

penalty in some other area until the situation became intolerable. Yet, any change in applying the conventional principles resulted in a net loss in effectiveness. Let's review briefly these conventional principles.

Classification. The first of these is known as classification. A classification is an arrangement of information in such a way as to prearrange data to give answers for specific questions. This cross listing builds up our classification headings to all possible combinations in order to outguess the questions and have all information "prearranged" (Figure 1).

Classification
1 Separation Processes
1.1 Absorption
1.2 Adsorption
1.3 Distillation
1.31 Conventional
1.32 Azeotropic
1.33 Extractive
1.4 Solvent Extraction
1.5 Thermal Diffusion

FIGURE 1—The "classification" system of indexing and retrieving information assembles concepts into classes according to order and likeness, then separates them according to order of unlikeness. The indexor has to try to outguess those who will use the system, and as a result we get classes, sub-classes, sub-sub-classes. Eventually the whole system becomes unwieldly.

But fixing the system to a prearranged solution can lead to eventual collapse as we are witnessing today with the Dewey Decimal System. We have to keep adding sub and sub-sub classes. The system becomes unwieldy.

The second principle used in storing information is the conventional alphabetical index. As distinguished from classifications, it is well known to everyone and includes dictionaries, encyclopediae, and indexes in the back of books.

The alphabetical index is only as complete as the point of view of the person entering the system. In order to outguess the question, we put in the names, cross references and other possible names, trade names and so forth, to make the index complete. Again we lengthen the list until we could have a volume the size of the Manhattan telephone directory. Of course a telephone directory just lists persons once by their last names. Suppose we wished to locate them by address, first name, profession, color of eyes, size of house, and so on. This certainly gets preposterous when you try to outguess the potential questions to the system.

Problems Encountered

What problems are encountered during the use of these documentation principles? They are problems involving differences of viewpoint and terminology. Specifically, they are problems of:

Determination of Logical Classes (viewpoints of individuals). Human beings are inherently unable to place any given concept in only one logical class. For example, we all think we have a good idea of what a tank is. Yet it is classed as an organic chemical, beverage, an anti-freeze, a solvent or however we use it. Take another example. It would thus seem that a tank could be described by placing it in one logical class. Yet, a little thought reveals that a tank may not only be a structure for storing liquid but also may be a pond or lake or an armored combat vehicle. The problem becomes even worse when combinations or concepts are involved. Consider "brick linings for tanks," a phrase which combines three concepts, each with its own individual problem of class determination, not to speak of the combined problem.

Generics (broadness or narrowness of viewpoints). This problem involves the "family trees" of concepts. Because each concept implies broader concepts, literature searching based upon broad concepts should effectively retrieve information based upon narrower but related concepts.

For example, retrieval of all information pertaining to publications should also (and automatically) result in obtaining all information on books, magazines, newsletters, and the like.

Semantics. This involves the relationships between words and their meanings. Not only are we concerned here with definitions, but also with synonyms, near-synonyms, homonyms, homographs, etc. Examples of semantically confusing words include "base," "color," "lead," "finish," and "tank."

Syntactics. This problem is concerned with word order. If syntax is disregarded, we may erroneously equate "cooling water" to "water cooling," "dog bites man" to "man bites dog," and "venetian blind" to "blind Venetian."

Technically feasible solutions to the four basic documentation problems have been well known for years. Then why haven't the solutions been applied to the conventional principles to thus enable creation of effective documentation systems? The answer is clear: If the solutions to the problems just noted were applied to the traditional principles of classification and conventional alphabetical indexing, we would have documentation systems so costly, complex, rigid and large that they would be worse than useless.

Classification is a suitable retrieval tool only when any of the following conditions prevail:

1. Subject is narrow in its scope.

2. Will be used only by small group of people who can learn it well and agree upon its categorizing conventions.

3. Number of documents involved is small and

4. Life of the classification need not be long.

CONCEPT COORDINATION SYSTEM

Recently, another documentation principle, concept coordination, has been developed. It appears to have great potential for solving the overall documentation problem. Concept coordination is based on the theory of intersect. By superimposing the terms of any random question, you get a coincidence of numbers that represent information sought (Figure 2). It is as simple as that.

Thus, just as innumerable English words can be constructed from the 26 letters of the alphabet, a great number of items can be described in a concept coordination system with a relatively small vocabulary (say 5000 words). Fortunately, when using the concept coordination principle, the first three of the basic documentation problems can be attacked and solved on the individual

concept level rather than on a total system level. This means that solutions to the problems can be applied with relative ease, a feature not possible when using traditional principles.

With concept coordination, "deep" indexing is practicable because of the relatively small system size. This itself results in greatly improved accessibility to information.

The three principles may then be compared as shown in Figure 3. The comparison is on the basis of equal retrievability or effectiveness.

Great Improvement. In all cases, concept coordination achieves the best performance. Based on this premise, the principle of concept coordination was used in documenting du Pont's Engineering department reports. Initial results using the concept coordination index showed a 100 percent improvement in effectiveness of information retrieval. In addition, the new index furnished at least one report for one third more questions than the old index.

It is significant to note that as the number of documents in the coordinate index system increases, the size of the vocabulary increases ever and ever more slowly. This reaffirms statements that technical language is limited and words are used over and over again. It is true that names and chemicals will tend to add words to the system's vocabulary—but once the technical words are compiled, few new ones will be added.

SOLVING DOCUMENTATION PROBLEMS

There are two basic approaches in solving documentation problems. The first is to search harder for the desired information, which has been stored away with relatively few "handles" for retrieval. This is the approach which has been attempted for centuries and which has become increasingly ineffective as the volume and complexity of information have grown.

The second approach is to increase redundancy at the input side of the system. By adding certain well-chosen words, we can provide more "handles" for retrieval, "handles" which may be useful from numerous viewpoints and with different terminologies.

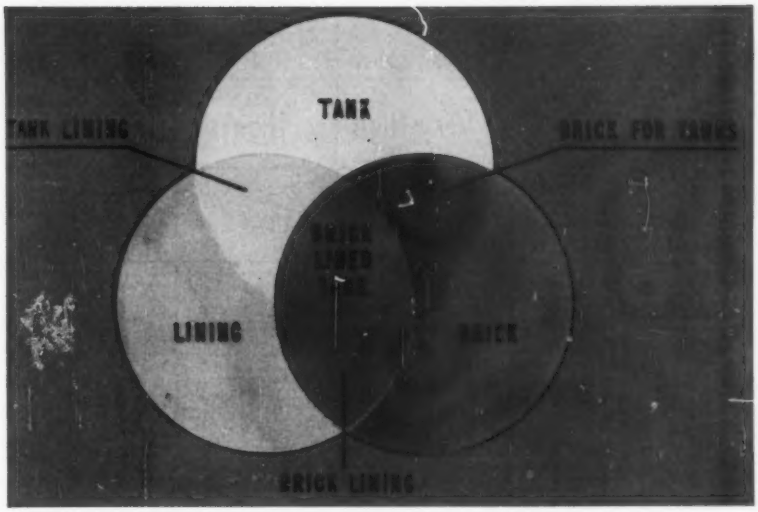

FIGURE 2—Information on "brick lined tank" is retrieved at the intersection of "tank", "brick" and "lining". Notice also, that there are fringe areas where just two concepts intersect. These offer information on "brick for tanks," "brick lining" and "tank lining."

Even had the first of these two approaches not been tainted with failure, the second method should be chosen for large documentation systems. Therefore, we must provide each document with index entries such that the user will have a satisfactorily high probability of retrieving it, no matter what his viewpoint or terminology.

Check List of Words. How can the indexer provide the needed index entries, without knowing what viewpoints and terminology potential users may employ? We have concluded that the indexer must be provided with a "check list" of words generally associated with those words. For example, if an author speaks of "distillation," the "distillation check list" should include such words as "rectification," "evaporation," "boiling," "separation," and so on. The indexer may choose from the "list" those words which would be appropriate index entries for the document at hand.

The "check list" thus consists of a vocabulary of words wherein each word's associations with other words in the vocabulary are specified. A descriptive name for such a device is "associative matrix." The use of the device results in "vocabulary control," which will bring into conjunction the vocabularies of originators and users of information, such that retrieval of information may be more effective.

Use of "Associative Matrix." Use of an associative matrix results in consistent indexing regardless of who does it. Such a vocabulary control does not eliminate the intellectual choice of proper words, new words and implied words, where necessary, nor is it mandatory to use the words listed. It does, however, minimize the guess work that plagues any indexer as to what he interprets from reading the document.

Thus it can be seen that an "associative matrix" solves the first three of the four basic, characteristic problems of documentation—logical class, generics, and semantics. The syntactical problem is not solved by an associative matrix. This last problem is of a manipulative nature rather than one arising from differences in human viewpoints and terminology.

Concept Coordination Classes. There are two classes of concept coordination systems. The classes are distinguished by their diverse use of "system units." "System unit" means an individual card, section of tape, or the like, which is manipulated during operation of the system. Class I systems have one unit per document. This class includes the "punch-card" system. Class II systems have one unit per vocabulary term or concept and includes "peek-a-boo" systems and coordinate indexes, such as uniterm. Class

	Classification	Alphabetical Index	Concept Coordination
Cost	Very High	High	Low
Simplicity	Very Poor	Poor	Very Good
Adaptability	Very Poor	Fair	Good
Compactness	Poor	Very Poor	Good

FIGURE 3—Comparison of the different systems for storing and retrieval of information.

II systems appeared to have significant advantages in index size, flexibility, and operating efficiency when large document collections must be handled.

TESTS OF CONCEPT COORDINATION

After a survey of the Engineering department's present documentation practices, principles, and needs, we decided to test two Class II concept coordination techniques. The purposes of the tests were:

1. To give first-hand knowledge of the utility, technical and economic advantages and disadvantages of various concept coordination techniques.

2. To provide illustrations of "documentation in action" which could be demonstrably extrapolated to broader applications.

3. Possibly, but not necessarily, to provide some permanent utility in the limited areas chosen for testing.

Reports Selected. Two areas in the department were chosen for testing. The first of these was 4,600 numbered Engineering department reports which receive wide distribution throughout the department and company. Present distribution lists average about 300 names. A collection, consisting of one copy of each report, requires about 150 feet of shelf space.

Subject coverage is very broad, ranging from the economic evaluation of various prospective plant sites to highly technical studies on frequency-response methods of process control.

The area of reports chosen was already well enough organized to permit application of new documentation techniques in the limited time available. It was a recognizable "unit" relatively well documented, and a good source of technical information which could be used more profitably should retrievability be improved.

We obtained copies of all reports included even the oldest reports so that we could later investigate effective methods of deletion. Approximately 15 engineer-weeks were consumed in indexing the reports for significant words and phrases.

At this time, no associative matrix was available. Accordingly, we used specialized techniques during analysis to insure that each significant word observed became a potential index entry. However, potentially "bound" phases were also made available as index entries. For example, a phrase such as "shielded arc welding" would be noted (during analysis) in all the following forms.

1. Shielded arc welding.
2. Arc welding.
3. Welding.

In addition, broader generic descriptions of the concepts involved were supplied by the analyzers.

Preparing the Cards. The analyses, consisting of significant words and phrases, were entered on a form sheet, with all existing conventional index entries. One form sheet was provided for each report, and one punch-card was prepared for each concept description listed on each form sheet. Each card contained not only a concept description, but also a report number. The 76,000 cards were verified, then sorted according to report number, then alphabetically by concept description. The sorted cards were mechanically tabulated. This tabulation served as a convenient set of abstracts arranged by report number.

The cards were again sorted and tabulated alphabetically by concept description and numerically by report number. This tabulation gathered together, under each concept description, the numbers of pertinent reports. About 12,000 concept descriptions were tabulated. On this tabulation we performed an initial editing to permit a reduction in vocabulary size while still retaining effectiveness.

The report numbers which resulted from the edited tabulation were then posted by hand on 5 x 8 uniterm cards. One card was provided for each concept description, be it one word or a phrase.

Final Examination. Then followed the most time-consuming activity of the entire effort. About 30 engineer-weeks were expended examining the hand-posted cards one by one. All participated in this activity, giving particular care to insure adequate treatment of synonyms and near-synonyms (by providing "See" and "See also" references).

Names of other companies were generally deleted except when past usage had been heavy. Also, a few words with very broad meanings were deleted. From the final editing operation, we obtained 3,900 cards, one card for each vocabulary concept or concept combination.

This index is used in the standard uniterm fashion. The searcher chooses a combination of concepts expressing his "question" and matches report numbers entered under each concept involved in the combination. The numbers which match will be those of reports pertinent to the question at hand. (Figure 4). The searcher then refers to a list of report titles, arranged in numerical order, to choose the most pertinent reports for further perusal.

"P.V." DRAWINGS

The second area chosen for testing was pressure vessel design

drawings. This area was chosen because it covers a narrow subject, as contrasted to E. D. reports. It is already well organized and it is part of a larger area (design drawings in general) wherein significant savings can be obtained by reusing a part of the large investment in already completed designs.

The system resulting from this test was expected to have little permanent utility because only a portion of the pressure vessel drawings could be retrieved and documented in the time available.

Of perhaps 12,000 pressure vessel drawings some 1,200 were already well organized via the medium of summary sheets, called "P.V. sheets." Eight hundred "P.V. Sheets" were chosen at random for this test. Each was deeply analyzed for a maximum of 98 questions or characteristics. We used the same "form sheet" technique as we did with E. D. reports; about 27,000 punch cards resulted. The cards were sorted and tabulated by characteristic number. From the tabulation and from discussions with Design division personnel, we found that only about 20 of the 98 indexed characteristics were significant.

A new form sheet was provided for each range of each significant characteristic. Some 175 form sheets resulted, on each of which were entered the P.V. numbers of the pertinent drawings. The form sheets were then sent to the key punch, where a punch card was prepared for each form sheet.

Space was dedicated (one position per P.V. sheet) in ten of the twelve positions in each of the 80 columns, for a total of 800 positions on an IBM card. In each card, holes were punched in positions corresponding to the P.V. sheet numbers pertinent to that particular characteristic or characteristic range denoted by the card title.

Using the P.V. System. In using this system, the searcher chooses the pertinent characteristics in which he is interested and picks the corresponding cards from the 175-card deck. If a quantitative range of the characteristic is involved, that particular range card is chosen. When all pertinent characteristics and range cards have been chosen, they are manually superimposed and the pertinent P.V. numbers are indicated by coincidence of holes (hence the name "peek-a-boo" system) in all superimposed cards. (See Figure 5). The searcher can then refer to the indicated P.V. sheets.

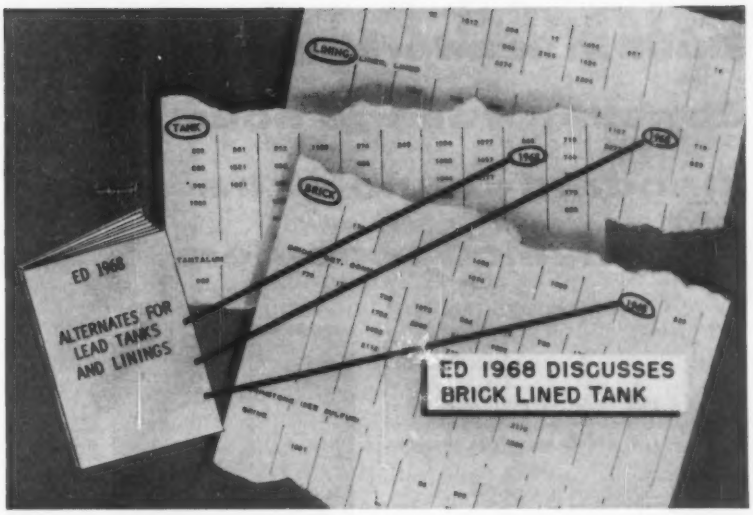

FIGURE 4—In using the coordinate index, the "searcher" chooses a combination of concepts expressing his question. He then matches report numbers entered under each concept involved in the combination. In this case, report 1968 discusses "brick lined tank."

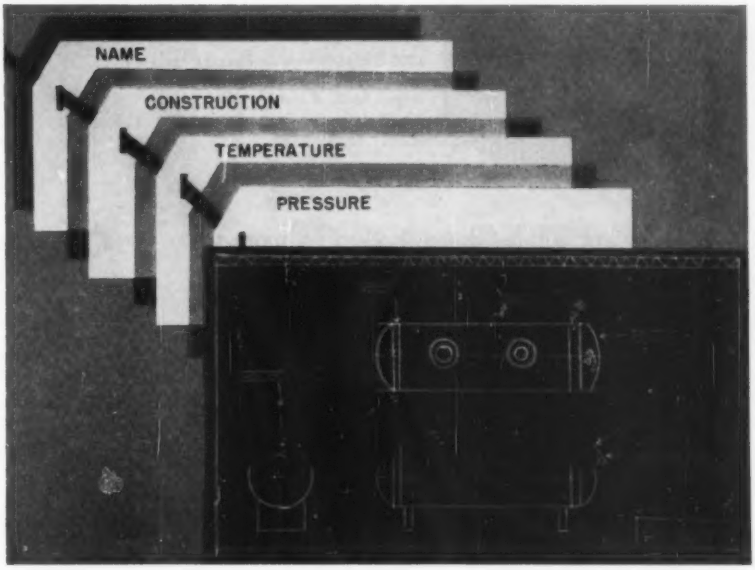

FIGURE 5—In this system, the "searcher" chooses the pertinent characteristics, then picks the corresponding cards. The cards are then manually superimposed and the pertinent information is indicated by the holes which line-up. Sometimes, this is referred to as the "peek-a-boo" system.

Test Results: The E.D. report index was quantitatively evaluated through the results obtained testing the index throughout the department. The following comparison was made against a good and extensive conventional index:

1. The coordinate index retrieves at least twice as many report numbers per reference question as does the conventional index.

2. The coordinate index retrieves at least 33 percent more requests than does the conventional index.

3. False drops have been negligible (less than 5 percent of the total report numbers retrieved).

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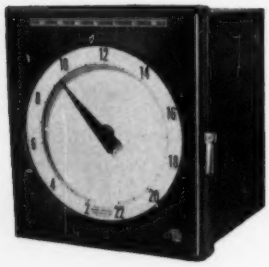

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ready done, is expected to be substantial, although it has not yet been fully evaluated.

CONCLUSION

We have drawn from this work a number of conclusions:

1. Especially in the technical information field, there is an urgent need for effective class retrieval. Class retrieval is where the searcher wants all information pertinent to a certain subject but may not know what documents, if any, are pertinent or how they have been previously classified.

Essentially all present-day documentation systems (files) are designed not for class retrieval but rather for specific retrieval. We depend almost completely upon classifications or conventional alphabetical indexes.

2. Our second conclusion is that we have the same problem everyone else has—our files are used less often than is desirable. As the years pass, and as the amount of stored information increases, poor usage of files will become critically undesirable. The reasons for poor usage appear to be three-fold:

- The majority of potential file users are engaged in creative efforts and are interested in class retrieval rather than specific retrieval.
- Retrievability is often poor, even when specific retrieval is desired. This is inherent in large classifications and indexes, as previously noted.
- Poor usage is the human tendency not to go to the trouble of looking up information, particularly when time and inconvenience are involved.

3. For our particular long-range purposes, there is only one new documentation principle to consider: concept coordination, which will permit either specific or class retrieval. Based upon initial indications from the tests, it seems that concept coordination is workable for all types of information scope and detail. However, material must be organized in an orderly fashion before it is subject to economical treatment.

4. Documentation cost via concept coordination will be, for the foreseeable future, almost independent of any machine costs. Most

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of the expense is in indexing ($2 to $30 per document), depending upon how deeply the document is to be indexed and upon the extent to which the associative matrix is to be employed.

Retrieval costs should be insignificant in the over-all picture. Machines will improve during this time but instead of costs decreasing, economic document storage capacity will rise. The largest economical systems available for 1958 would handle only about 100,000 documents. Capacity may well be quadrupled by 1962 and then rise rapidly within a few years to the 10,000,000 (and above) range.

5. From this, it is concluded that only the most valuable documents should be well documented for the next 5 to 10 years because space will not be available "in the system" for those of lesser value. "Most valuable documents" are defined not necessarily as those which cost the most to produce but rather those which have the highest product of two factors: Retrieval frequency and value per retrieval. Means of defining these factors for each document type should be developed before widespread use of concept coordination.

6. The last conclusion is that, based on present and foreseeable conditions, it probably will be most economical to have one specialized system for retrieving only information "addresses." Then have another specialized system for mechanically supplying the actual information or documents. More document "addresses" will be economically retrievable than documents themselves. Hence, a combined system, requiring both actions for every document, would be uneconomical.

It is apparent to us, as it is to you, that manual methods of handling concept coordination cannot for long meet the documentation requirements of large organizations. Fortunately, these manual methods and indexes can be translated almost automatically into mechanical methods and indexes when the proper and adequately economical machines are developed. This we must be, and we intend to be, prepared for.

Presented at the Semi-Annual Meeting, ASME, Detroit, June 15-19, 1958.

EDITOR'S NOTE

Information received recently from Du Pont indicates a number of refinements made to the system described in this article. Much design and other engineering information (not normally included in formal reports) have been added to the collection.

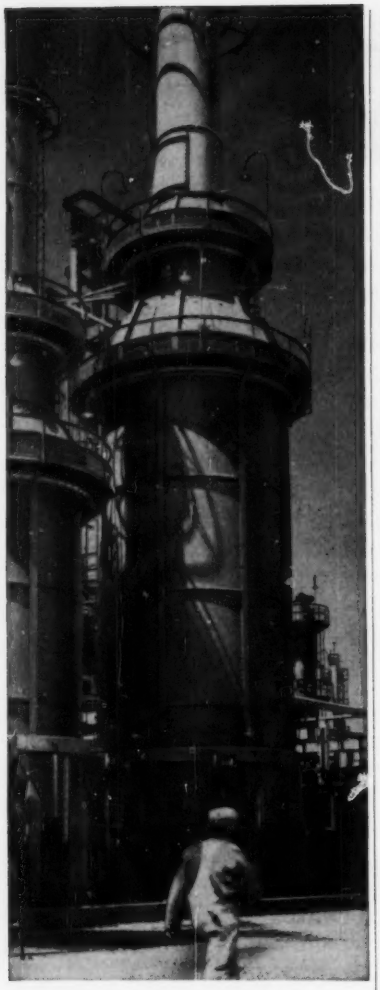
It is now recognized that the "associative matrix" (now improved) can be employed as a thesaurus during either input to or output from the storage system; i.e., to provide either improved indexing (which simplifies retrieval) or alternately the ability to ask complex questions during retrieval (which simplifies indexing requirements). The choice of point-of-use depends largely upon the rate ratio of reference questions to document accessions.

Depth of indexing has increased and accordingly has been found advisable to formalize some simple solutions to the syntactical problem (which was discussed briefly). This problem is adequately solved by an intellectual (not physical) sub-sectioning of each document into associations of related concepts and by employing a few symbols to indicate the role each concept plays in each particular document. Similar techniques are emplyed in experimental systems developed by the U.S. Patent Office.

Mechanization of Du Pont's retrieval operation is becoming more desirable and the Engineering department has installed a "Special Index Analyzer," a low-cost punch-card device for searching indexes which are arranged in "Class II" fashion.

About the Author

Thomas W. Schwartz is an industrial engineer for ITT Laboratories, Nutley, N. J. Holder of a B.S. degree from New York University, he is a specialist in documentation and information handling, and has been a management consultant with Du Pont's Engineering Services division for three years. Before that, he was a lecturer in industry at Taylor Management Laboratory, Wharton School, University of Pennsylvania. He has conducted industrial engineering activities in the United States and Germany, and has been with Yale & Towne Manufacturing Co. and Bigelow Sanford Carpet Co.



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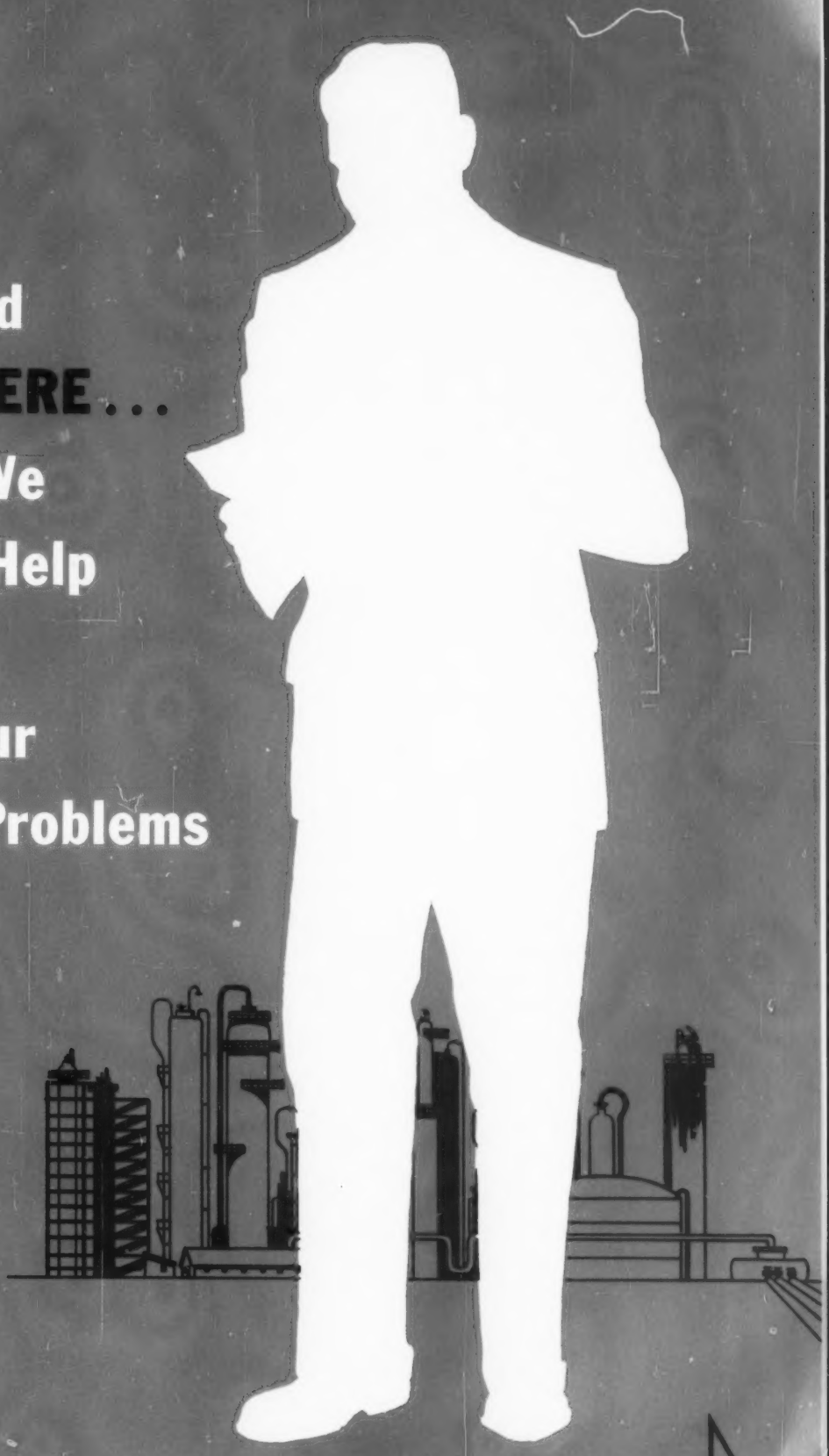

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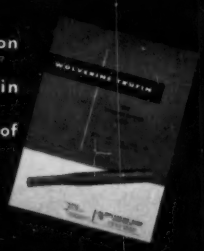

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What's Happening...

Oil's Earnings Continue to Improve

EARNINGS in the petroleum industry continued to recover in the first quarter of 1959, after having begun to improve in the third and fourth quarters of 1958. Results had been unfavorable in the latter half of 1957 and the first half of 1958.

For 39 companies, combined net income in the first quarter of 1959 was $697,693,000. That was $116,195,000 or 20 percent more than the same companies earned in the first three months of 1958. It was $22,036,000 or 3.3 percent more than they earned in the relatively good fourth quarter of 1958.

Increases in earnings in the petroleum industry have been less than those in some other industries. That was mainly because oil earnings did not shrink as badly during the recession.

During the present second quarter of 1959, oil companies are continuing to experience favorable financial results. Volumes of business are large, for the season, as petroleum demand remains well above a year ago. Prices of oils have held fairly firm, although ample supplies have prevented upward revisions of prices.

For the remainder of 1959, it is generally hoped that oil industry earnings will continue favorable. Some companies foresee a possibility that profits for the year may equal those of 1957, although others may not show that much recovery.

For all but a relatively few companies, earnings in the first quarter of 1959 were greater than those in the initial period of 1958, when industry conditions were around their worst of the recession.

But first quarter 1959 results were only slightly better than those of the final quarter of 1959 for the industry as a whole, as shown by the increase of only 3.3 percent for 39 companies. As might be expected, on the basis of that over-all change, only about one half of the 39 oil companies here considered showed more profit in the 1959 first quarter than in the 1958 fourth quarter, while the other half showed decreases.

Changes in earnings from the fourth quarter of 1958 to the first quarter of 1959 varied rather widely from company to company, ranging from gains

Net Earnings of Some Oil Companies in First Quarter, 1959 and 1958, and Fourth Quarter, 1958

(All earnings per share are on basis of common shares outstanding March 31, 1959)

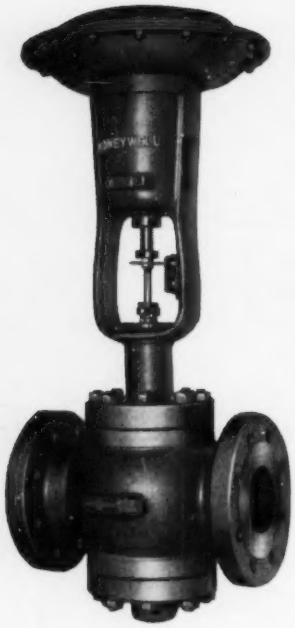
COMPANY	1st Quarter 1959		1st Quarter 1958		% Dif. 1st Q 1959—1958	4th Quarter 1958		% Dif. 1st Q 1959—4th Q 1958
	$Thousand	$Per Share	$Thousand	$Per Share		Amount	Per Share	
Amerada Petroleum Corp.	6,383	1.01	5,551	.88	+ 15.0	6,958	1.10	— 8.3
Anderson-Prichard Oil Corp.	1,347	.75	659	.34	+ 104.6	1,043	.60	+ 29.2
Argo Oil Company	1,435	.74	1,500	.77	— 4.3	1,164	.60	+ 23.3
Arkansas Fuel Oil Corp.	1,899	.50	2,305	.60	— 17.6	2,545	.67	— 25.4
Ashland Oil & Refining Co.	3,933	.61	2,466	.36	+ 59.5	3,232	.49	+ 21.7
Atlantic Refining Company	11,902	1.28	8,990	.26	+ 32.4	14,645	1.59	— 18.7
Bishop Oil Company	5	01	27	.05	— 80.6	70	.12	— 92.5
Cities Service Company	13,661	1.27	13,504	1.26	+ 1.2	12,580	1.17	+ 8.6
Clark Oil & Refining Corp.	504	.34	159	.11	+ 217.0	784	.54	— 35.7
Colorado Oil & Gas Corp.	426	.09	330	.06	+ 29.1	686	.22	— 37.9
Continental Oil Company	14,379	.73	10,699	.55	+ 34.4	14,171	.72	+ 1.5
Crescent Petroleum Corp.	686	.33	470	.19	+ 46.0	.....	.....	.....
Delhi-Taylor Oil Company	2,509	.48	d—246	d—.05	.....	d—546	d—.10	.....
Gulf Oil Corporation	66,673	2.06	60,668	1.87	+ 9.9	125,140	3.86	— 46.7
Honolulu Oil Corporation	3,485	.93	3,398	.91	+ 2.6	3,250	.87	+ 7.2
*Humble Oil & Refining Co.	44,032	.61	32,300	.45	+ 36.3	.....	.....	.....
*Imperial Oil, Ltd.	13,560	.43	15,022	.48	— 9.7	16,293	.52	— 16.8
*International Pet. Co.	5,400	.37	4,900	.34	+ 10.2	.....	.....	.....
Louisiana Land & Expl. Co.	4,264	.48	4,800	.53	— 11.2	4,392	.49	— 2.9
Maracaibo Oil Expl. Corp.	66	.13	91	.19	— 27.5	119	.24	— 44.5
Ohio Oil Company	10,198	.78	8,368	.64	+ 21.9	9,128	.70	+ 11.7
Phillips Petroleum Co.	25,833	.75	20,517	.60	+ 25.9	26,628	.78	— 3.0
Plymouth Oil Company	1,527	.60	807	.32	+ 89.2	1,712	.67	— 10.8
Pure Oil Company	5,591	.65	4,732	.55	+ 18.2	11,406	1.32	— 51.0
Quaker State Oil Ref. Corp.	448	.54	289	.35	+ 55.0	551	.67	— 18.9
Richfield Oil Corporation	5,585	1.39	5,605	1.40	— 0.4	4,828	1.20	+ 15.7
Shell Oil Company	34,500	1.14	30,500	1.01	+ 13.1	38,274	1.26	— 9.9
Signal Oil & Gas Company	4,329	.50	4,209	.49	+ 2.9	.....	.....	.....
Sinclair Oil Corporation	17,184	1.12	15,219	.99	+ 12.9	14,105	.92	+ 21.8
Sinclair Venez. Oil Co.	3,895	.97	4,131	1.03	— 5 7	.....	.....	.....
Skelly Oil Company	6,695	1.16	6,014	1.04	+ 11.3	10,143	1.77	— 34.0
Socony-Mobil Oil Co., Inc.	45,200	.93	36,900	.76	+ 22.5	41,086	.85	+ 10.0
Standard Oil Co. of Calif.	57,597	.91	57,411	.91	+ 0.3	70,015	1.11	— 17.7
Standard Oil Co. (Indiana)	44,684	1.25	31,432	.88	+ 42.2	31,326	.88	+ 42.6
Standard Oil (Kentucky)	3,264	1.25	3,240	1.24	% 0.7	3,612	1.39	— 9.6
Standard Oil Co. (N. J.)	167,000	.78	146,000	.68	+ 14.4	100,475	.47	+ 66.2
Standard Oil Co. (Ohio)	8,505	1.72	4,318	.85	+ 97.0	6,570	1.32	+ 29.4
Sun Oil Company	11,227	.96	6,174	.53	+ 81.8	9,439	.80	+ 18.9
Sunray Mid-Cont. Oil Co.	9,743	.56	9,653	.56	+ 0.9	12,583	.68	+ 22.6
The Texas Company	91,220	1.56	70,003	1.20	+ 30.3	82,475	1.41	+ 10.6
Texas Pacific Coal & Oil Co.	2,020	.52	1,496	.39	+ 35.0	2,065	.53	— 2.2
Tidewater Oil Company	10,463	.74	803	.....	+1,203.0	2,928	.16	+257.3
Union Oil Co. of Calif.	4,890	.60	5,994	.73	— 18.4	4,169	.53	+ 17.3
Union Oil & Gas Corp. of La.	3,650	.77	2,216	.47	+ 64.8	.....	.....	.....
Universal Consol. Oil Co	780	.81	482	.50	+ 61.8	846	.88	— 8.0
Woodley Petroleum Co.	668	.78	640	.75	+ 4.4	1,060	1.24	— 37.0
*Total, 39 Companies	697,693	.....	581,498	.....	+ 20.0	675,657	.....	+ 3.3
*Total, 43 Companies	710,253	.....	592,524	.....	+ 19.9	.....	.....	.....

* Humble, Imperial, and International are excluded from totals, being included as affiliates of Standard (N. J.).

d. Deficit.

is your

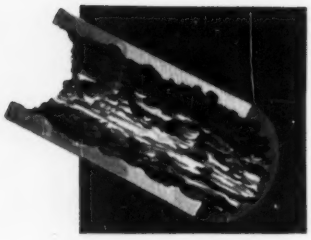
PROCESS FLOW EROSIVE?



Type 11, double-seated

Type 10 angle valve

Honeywell control valves are available for a wide range of conditions



Whether you're talking about suspensions or high pressure drops, there's a Honeywell automatic control valve for your erosive process flow. The new Honeywell Type 10 angle valve is excellent for slurries, viscous or flashing flow mediums . . . all Honeywell valves are available with a variety of trim for high pressure drop service. Choice of trim, for any type of erosive condition is made from 17-4 PH, *Stellite*, 440C and *Colmonoy* Coating.

For erosive or non-erosive flows . . . or other process flow conditions . . . Honeywell valves are available in a wide range of types and sizes. When you need control valves . . . contact your local Honeywell field engineer. Write for new Catalog C800-1.

MINNEAPOLIS-HONEYWELL, Fort Washington, Pa.

Honeywell

H HONEYWELL *First in Control*

of about 30 percent or more for a number of companies to decreases of more than 40 percent for several. However, about one half of the companies showed less than 20 percent increase or decrease. That group with middle ground changes included several international companies, numerous integrated companies, and several producing companies.

Some of the larger increases, around 30 percent or better, were reported by Tidewater Oil Co., Standard Oil Co. of Indiana, Standard Oil Co. (Ohio), and Anderson-Prichard Oil Corp. Gains of 20 to 25 percent were shown by Argo Oil Co., Sunray Mid-Continent Oil Co., Sinclair Oil Corp., and Ashland Oil & Refining Co.

1960 API Meeting to Be Held in Detroit Next May

The 1960 midyear meeting of the API Division of Refining will be held in Detroit, May 9-12. Registration for the last meeting was close to 1,600 refiners, technologists, scientists and others. Thus it failed to top the previous all-time record for attendance set in Houston in 1954.

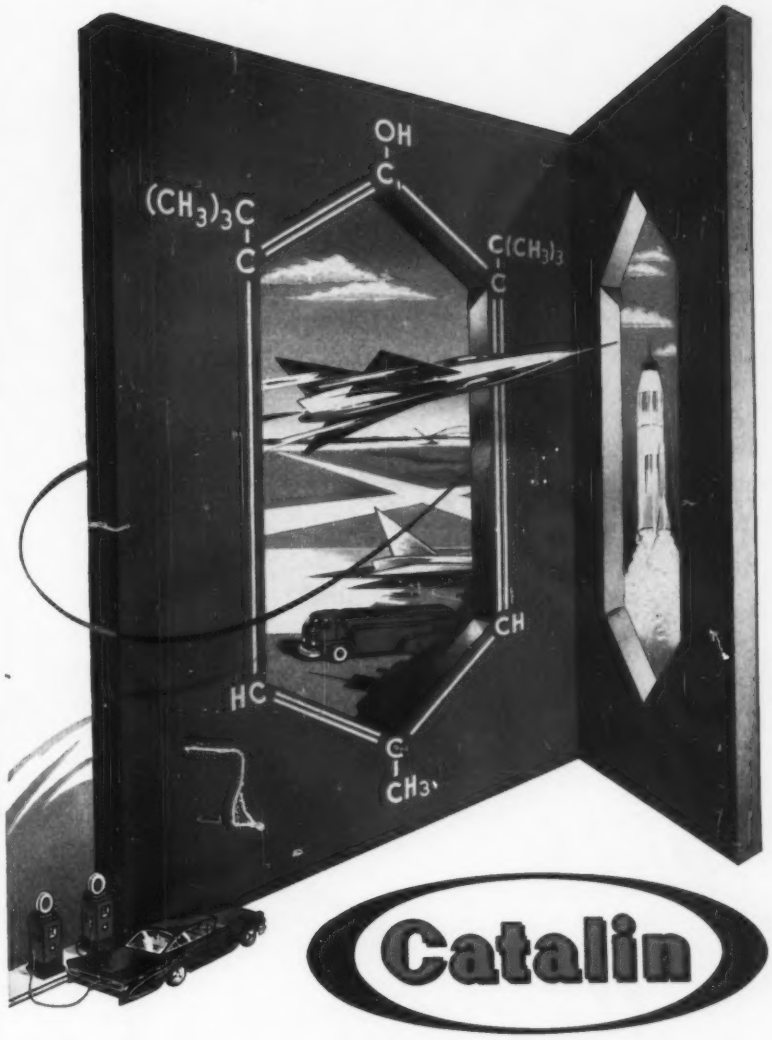
Pemex Looks to Industrial America for Investment

Oil will be the backbone of the Mexican economy for many years to come, according to Pascual Gutierrez Roldan, newly appointed director general of Petroleos Mexicanos. This statement was made before leading oil executives at a luncheon tendered to Roldan by John B. O'Connor, president of Dresser Industries, Inc., Dallas.

Roldan offered the hand of friendship and welcome to industrial America in a sincere and enthusiastic invitation. In part, he said, "The oil industry of Mexico becomes all important, when we consider that Pemex's economic situation makes such a tremendous impact upon all other activities. The simple revelation that the Pemex budget amounts to 70 percent of our country's entire national budget has not heretofore been generally known. Oil production in Mexico determines in a direct way the possibilities of industrial integration and clearly indicates why Mexco's economy depends on Pemex's economy.

We must integrate our industry to satisfy the growing demands in our country and to increase the over-all revenue of Pemex. In order to do this, we are going to expand into the field of petrochemicals. In this we have decided to make three different approaches which will be of great interest to American oil men and industrialists:

- Capital investments made by Pemex which are of prime importance to the industrial development of Mexico and where Pemex will maintain absolute control.
- In another area Pemex will invite



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antioxidant CAO-1

98.9% PURE* sets the highest standards for purity and effectiveness

Catalin ANTIOXIDANT CAO-1 . . . the field's finest grade of 2,6-ditertiary-butyl-para-cresol . . . meets U. S. Government military specifications for use in aviation gasolines, turbine and jet fuels. A major advantage achieved with this heat-resistant, water-insoluble antioxidant is that high-octane fuels are effectively protected, with no loss of octane rating. Gum and peroxide formations are inhibited, and deposits in the aircraft intake manifold and engine are markedly reduced.

Catalin ANTIOXIDANT CAO-1 stabilizes high-octane automotive gasolines, as well as turbine, insulating, hydraulic and transformer oils . . . in fact, nearly any petroleum hydrocarbon exposed to oxidizing conditions.

Samples, literature and technical assistance wait upon your request. Inquiries invited.

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chemicals plastics resins

* *Typical Analysis*

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private enterprise to cooperate for the mutual benefit of the investors.

• A wide open area in which Pemex will act as the promoter or expeditor to give an opportunity, 100 percent, to a private enterprise in order that the chemical industry in Mexico may push ahead and develop more rapidly. Immediate plans are now going ahead to make the oil, steel, and chemical industries the three principal supporters of Mexico's national economy, in order to free our future from the hazards of dependence on a single source of income."

Low-Cost Process to Upgrade Distillates

A new low-cost process for upgrading petroleum distillates has been announced by Nalco Chemical Co., Chicago. The process, Nalfining, creates no disposal problems, needs minimum supervision and can be put into operation for an equipment investment of 50 to 75 cents per barrel of processing capacity, compared with up to $300 for some other processes, Nalco officials said. Available under license from Nalco, it results in no loss of salable oil and requires minimum processing time.

Nalco research engineers said Nalfining is particularly applicable to upgrading light fractions such as home heating and diesel fuels, kerosene, gasoline, jet fuels and solvents. The process will eliminate odors, sharply reduce sludge formation and corrosion, and improve stability.

Nalfining utilizes a bulk chemical, acetic anhydride, to inactivate unstable, reactive contaminants such as sulfur, nitrogen and complex organic compounds present in petroleum distillates. The interaction between acetic anhydride and the reactive contaminants is followed by contact with caustic.

The new process does not necessarily reduce the total sulfur or nitrogen content of a distillate stock, the researchers said. And although conventional sweetening and caustic wash processes have little effect on nitrogen-containing impurities, such as pyrolles, Nalfining rapidly converts them to innocuous reaction products.

Process vessels or treating tanks available from caustic or acid treating operations can be adapted to the Nalfining process. Aluminum storage, tanks, pumps, and lines to handle acetic anhydride normally are the only new equipment required.

Octane Numbers on Way Up, Says Ethyl Executive

Average octane numbers of gasoline will climb three to five points during the next five years, predicts J. A. Costello, vice president of The Ethyl Corp., New York. Putting today's averages at 99 for premium gasoline and 92 for regular grade, Costello said premium "might reach an octane number as high as 102 to 104, and regular grade gasoline might get to 95."

He attributed the moderation in recent years of the historical rise of octane numbers to stabilization of the octane requirement of new engine designs and to "the very high cost per octane number at the higher levels that have been reached." He said it costs between one-half and three-quarter cent to raise the octane number of one gallon of gasoline from 99 to 100.

'Fingerprinting' System For Crude Oil Samples

A new method of "fingerprinting" different types of crude oil is helping scientists solve the mystery of its origin and composition so petroleum products can be made more efficiently and economically. J. C. Winters, analytical research scientist for Standard Oil Co. (Ind.), said new techniques using gas chromatography analysis in a 12-hour period can determine the component parts in a crude oil sample.

In contrast, he pointed out, a project using former methods to analyze a single Oklahoma crude oil began about 1929, and since then more than 300 man-years have been spent on the study.

"By traditional methods, the time and money needed to gather sufficient data to formulate valid broad concepts about the composition of crude oil would be

HOW MANY YEARS WILL A GOOD LINING LAST?

Make it with Hexmetal

AND DOUBLE THE NUMBER YOU FIRST THOUGHT OF

A lining lasts as long as its bonding properties.

The natural organic bond of refractory clays and the chemical set of concrete all fail eventually under the stresses imposed upon them. When a lining is "bonded" or given "bone" by Hexmetal Reinforcement, it holds in position long after all its natural bond is burnt out by heat or chemical action. The independent pinned joint of Hexmetal cells give twice the life of other reinforcements with lug joints.

Industry is year by year proving the value of these claims in Flues, Ash-Pits, Reactors, Cyclones, Cat Crackers, Coke Hoppers, Down Comer Pipes, Hydroformers, Water Turbine Flumes, Underground Galleries, etc.

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Stainless Steel pipes cool hot acid

AT SINCLAIR REFINING COMPANY,
HOUSTON, TEXAS

This continuous SO_3 sulfonization unit produces a high detergent lube oil additive. The picture shows Type 316 Stainless Steel pipes in the cooler. 98% sulfuric acid enters the coils at about 145°F and is cooled to 105°F by water.

The pipes take punishment three ways: high temperature, acid corrosion, and erosion. At first, some of the pipes were made of a less resistant metal but they had to be replaced with Stainless Steel after only eight months. There has not been one sign of deterioration in the replacements or in the Stainless Steel pipes installed originally.

When you install equipment, design it with the right material from the start. If you need strength and corrosion resistance, there is no metal that can match the performance and economy of Stainless Steel. Order USS Stainless Steel through your U. S. Steel representative or your local Steel Service Center.

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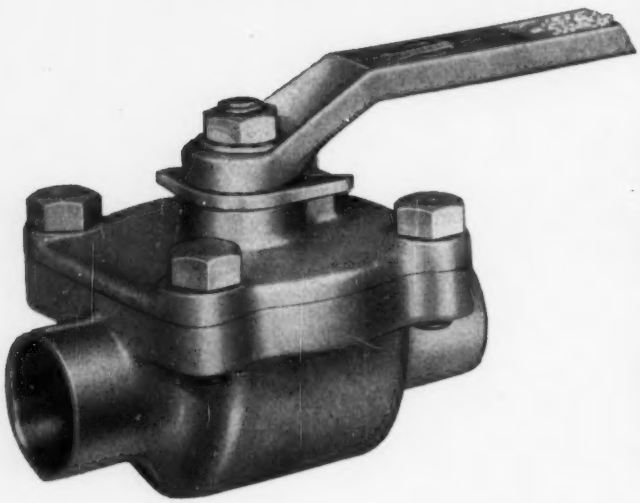
Simple to Service ...on-the-line!



The Rockwood Top Entry Ball Valve

Here's the advanced-design ball valve that's practically as easy to service as it is to operate. Ideal for oil, gas, oxygen, or hazardous liquids, it's a real time and money saver. Check the specifications below, then mail coupon for complete details.

Specifications: Cast Bronze; Buna N Seals; Forged Hard Chrome Plated Ball; Beryllium Copper Spring; Buna N Seats (also available in Teflon, nylon, and Viton-A); Sweat or Thread Ends; Sizes: ½″, ¾″, 1″, 2″; 300 p.s.i. — W.O.G.

ROCKWOOD BALL VALVES

FULL, ROUND FLOW

Distributors in all principal industrial areas

ROCKWOOD SPRINKLER COMPANY
220 Harlow Street, Worcester 5, Mass.

Please send me complete details on the Rockwood Top Entry Ball Valve.

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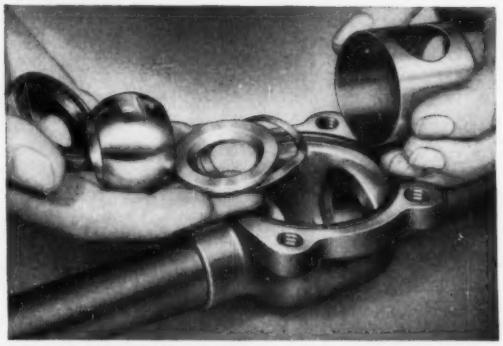
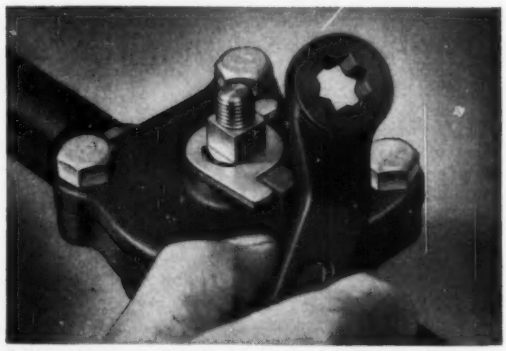
City.....*Zone*.....*State*.....

Direction of shut-off can be changed merely by reversing cage assembly. After removal of four screws, the body cap lifts right off, permitting access to the internal parts of the valve without removal from the line.



Changing Type of Seat: Cage assembly removes easily without special tools. Seat, seat retainer, spring, retainer, and ball removed as one unit for service or replacement.

Cleaning: Simple design and construction of body permits valve to be completely cleaned quickly and easily.



8 Ways Easier to Handle During Installation and Operation, Too — because square stem design permits on-off operation in any of 8 positions. Rugged stem keys directly into floating ball.

prohibitive," Winters said. "Our approach differed from the conventional by the use of gas chromatography as a rapid and inexpensive method of characterizing crude oil by isomer distribution through seven carbons."

Motor Oil Performance Tested with Cleveland Cabs

The average motorist is not realizing maximum performance of his motor oil or filter if crankcase drain intervals are extended excessively, according to tests made with a fleet of 81 Cleveland taxicabs. This was the highlight of a special report made by R. K. Williams, of Lubrizol Corp., Cleveland, and W. S. James, of W. S. James & Associates, at a recent meeting of the Lubrication committee, Division of Marketing, API.

Williams said there is a direct relationship between engine cleanliness and drain intervals. He said the amount of sludge and varnish in crankcase oils increases with the extension of drain intervals, and that effectiveness of crankcase oils decreases proportionately. He added, "our data raise a serious question regarding the ability of some high quality detergent additives to control sludge effectively when drain periods are too long."

Williams said some car manufacturers are recommending longer oil change intervals. One result of this, he added, is that the average interval for oil drains has increased from 1,900 miles in 1952 to 3,100 miles in 1958.

Crude Oil Demand to Slump for Four States

Crude oil demand in June is expected to be down for four key states, according to the Bureau of Mines. The forecast is as follows:

- Texas, 2.6 million bpd, down 130,000 from May forecast.
- Kansas, 335,000 bpd, down 15,000 from May.
- Oklahoma, 560,000 bpd, down 10,000 from May.
- New Mexico, 295,000 bpd, down 5,000 from May.

Patent for CO_2 Removal Is Issued by Interior

A patent covering the hot potassium carbonate process for CO_2 removal has been issued to the Federal Government by the Department of the Interior. The new method, offering substantial savings to makers of synthetic ammonia, chemicals, and other products, already is being used commercially by plants that were granted licenses under the Department's pending patent application.

Similar licenses are available to others who may wish to use the method in this country. Such licenses, under the Department's regulations, would be royalty-free and nonexclusive. U.S. rights to the process are assigned to the Department under U.S. Patent No. 2,886,405.

No Future Oil Shortage Foreseen by Gulf Oil VP

There is plenty of oil to meet the Free World's needs for a long time to come; however, only 36.8 billion barrels of it are located in the United States. That was the way Dr. Jerry McAfee, a vice president of Gulf Oil Corp., answered the question, "How Much Oil Do We Have and Where Is It?" at a recent meeting of the North Carolina Oil Jobbers Association. His talk pointed out that the United States has only about 11 times its annual consumption in reserve, whereas the Free World has an 82-year supply of about 215 billion barrels in its reserve bank.

Happenings . . .

Dr. McAfee added that the thousands searching for oil throughout the world, will find more billions of barrels to add to the oil bank before the present reserves are withdrawn. He predicted future oil discoveries are likely to be much more frequent abroad than in this country.

McAfee added that price increases caused by higher exploration costs would have to reach as much as 65 percent higher than the current average price of $3 per barrel. The unlikelihood the public would accept any such price increase, he said, indicates it is unrealistic to entertain seriously the idea that this na-

Conveyor carries drums through entrance tunnel into incinerator. Arch, walls and floor are "zone-lined" with Plibrico plastic and castable refractories. These form a joint-free durable lining giving long service life and extra protection against thermal shock and abrasion.

New Plibrico Incinerator at J. & B. Smith Co. "burns" metal drums clean

...SAVES $1100 A WEEK!

Now, tough to clean 30 and 55 gallon drums caked with oil, paint, bituminous or other products are cleaned faster, safer and for less cost. Upended drums are conveyed through the Plibrico incinerator at the rate of 120 an hour, where controlled heat burns out the unwanted materials which drop into a collection pit.

Smoke-and odor-free cleaning. Prior to the installation of this new Plibrico incinerator all drums had to be transported and open-burned outside the city because of obnoxious smoke and fumes. All this expensive handling was eliminated with the Plibrico incinerator. Drums are now burned right on the firm's own premises in Atlanta.

WRITE NOW FOR DETAILED CASE HISTORY . . . ask your local Plibrico Field Engineer to show you how modern incineration solves other reclamation and waste disposal problems in your field.

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Plibrico Sales & Service in Principal U. S. Cities & Canada
REFRACTORY PRODUCTS · ENGINEERING · CONSTRUCTION

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tion can even maintain its present 84 percent of self sufficiency in oil, to say nothing of becoming self sufficient.

Dr. McAfee said, "Any reduction in the depletion provision would tend to reduce the supply of oil in the U.S. and to raise its price, with consequent ill-effects upon marketers and refiners, as well as upon the producer himself. Everyone in the industry should wholeheartedly oppose any extension of government regulation, because one regulation usually leads to another, and nothing will more quickly or more certainly stifle the energetic initiative on which our free economy is based than excessive government control."

Du Pont Report Predicts Demand Increase for Fuel

Motor fuel demand in the second quarter of 1959 should be more than 3.8 percent ahead of the second quarter of 1958, according to a report issued recently by E. I. duPont de Nemours & Co.'s Petroleum Chemicals division.

The forecast increase is entirely in domestic motor fuel inasmuch as export demand is expected to remain unchanged from the same period last year.

The 3.8 percent increase in motor fuel demand breaks down into an increase of 3.7 percent for domestic motor gasoline and 6.1 percent for domestic aviation gasoline. It was pointed out that the growth in aviation gasoline should reach its peak this year. Both military and civil usage should decrease as jet and turboprop aircraft increase in number.

In reviewing figures for the first quarter of 1959, the DuPont report noted that while motor fuel demand is 6.4 percent higher than a year ago, the estimated gains are distorted by the abnormally low rate of consumption during the first quarter of 1958 when a combination of weather and economic conditions adversely affected demand.

Gasoline Consumption Hits Record Peak in U. S.

Consumption of gasoline in the United States hit a record peak of 59.1 billion gallons in 1958, an increase of 1¾ billion over the previous high of 57.4 billion in 1957. The API provided this estimate in its annual consumption report. Estimates are based on figures supplied by state governments, and reflect all gasoline sales, whether for taxable or tax-exempt purposes.

California continued its role of biggest state consumer, by far. It accounted for 5.7 billion gallons in 1958, an increase of almost 300 million over 1957.

Texas held its position as the second biggest state consumer, requiring 4.7 billion gallons. New York was third with slightly better than 4 billion — marking the first time that the Empire State consumers had crossed the four-billion threshold. Pennsylvania slipped past Ohio as the fourth state, reporting 3.2 billion gallons versus Ohio's 3.1 billion. Other states in the first 10 are Illinois, Michigan, New Jersey, Florida and Indiana.

Fluor to Use Giammarco-Vetrocoke Treating Process

The Fluor Corporation, Ltd., has been licensed to design and erect gas treating plants using the Giammarco-Vetrocoke processes. These new gas treating processes permit the removal of hydrogen sulfide and carbon dioxide from industrial gases with significant reduction in both investment and operating costs. They have broad application in the treating of natural gas, refinery gases, coke-oven gas, and petrochemical synthesis gases. The economic advantage of these processes is derived from the high rates of absorption and desorption of acid gases in the new Giammarco-Vetrocoke solutions.

High Octane Race to Slow, Says Standard Researcher

The race for higher gasoline octanes is expected to slow down for "some time" according to Standard Oil Co. (Ind.) research coordinator John B. Duckworth. The four reasons he gave were:

- Engine roughness and rumble are deterrents to further compression ratio boosts.
- Quality of premium gasoline cur-

ON THE SPOT
for
immediate
delivery

Diethylene Glycol
Triethylene Glycol
Ethanolamines

For removal of water, hydrogen sulfide and carbon dioxide from natural gas streams—local stocks are available for on-time delivery schedules to fit your processing requirements.

In the Southwest, call Ranger Chemical Company, Houston, Texas, or Western Chemical Company, Odessa and Borger, Texas, and Farmington, New Mexico. Tank car, tank truck, and drum shipments are also available from the Brandenburg, Kentucky, plant.

For data sheets, samples and information, see your Olin Mathieson representative or write today.

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Reactors withstand hot phosphoric acid 4 years

. . . 316L stainless steel protects them

Clad with Nickel-containing Type 316L stainless steel, these two reactors have been handling a 375°F phosphoric acid catalyst for 4 years. . . . They're still doing well! No down time. Little maintenance.

The 316L stainless steel not only contends with phosphoric acid corrosion in this equipment . . . but also with thermal stresses and with abrasion from quartz packing.

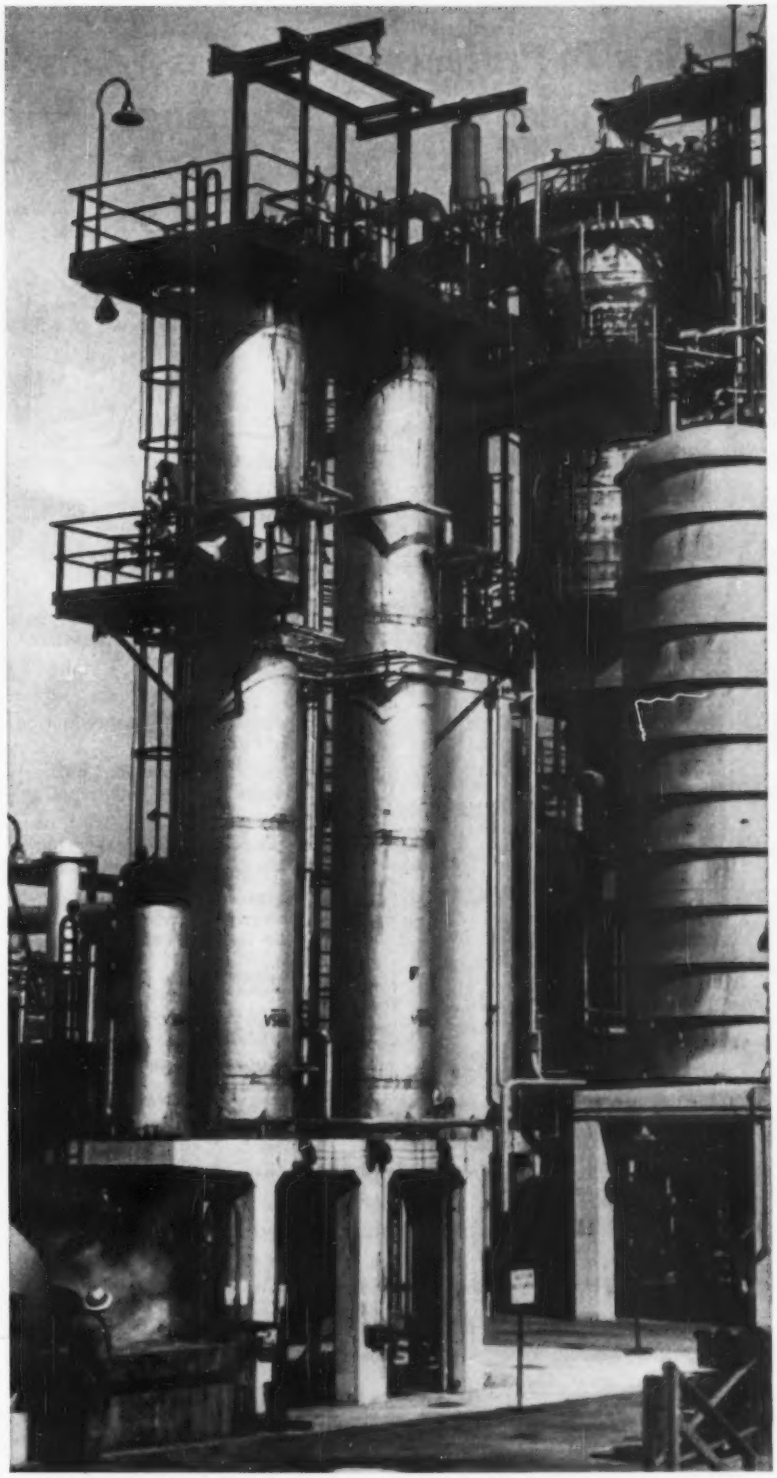
Nickel-containing stainless steels have an enviable record in refineries

Nickel-containing stainless steels reduce maintenance costs in many corrosive areas of refineries: in crude topping towers, in sulfuric acid lines of alkylation units, in furfural separation towers.

When you're designing equipment for handling corrosives, it will pay you to investigate the low-maintenance benefits of chromium-nickel stainless steels.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street INCO New York 5, N. Y.



Lukens Stainless-Clad Steel handles 375°F phosphoric acid for over 4 years. These polymerization reactors at the Standard Oil Company of British Columbia Limited Refinery in Burnaby, British Columbia, are protected from hot phosphoric acid and abrasion by Nickel-containing 316L stainless steel cladding.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

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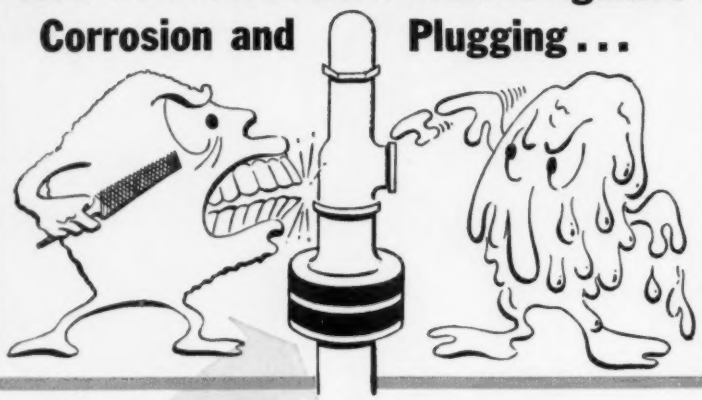
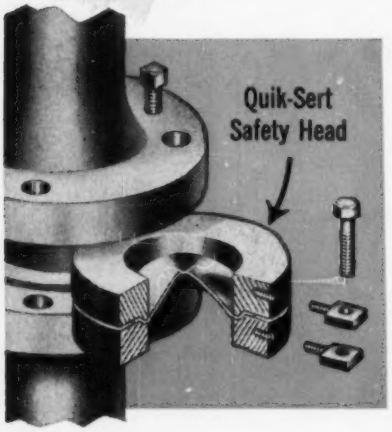
How To Protect Relief Valves Against Corrosion and Plugging . . .



BS&B *Safety Head* Is A Damage Barrier That Doesn't Change Valve Operating Accuracy

A BS&B Quik-Sert Safety Head mounted to the inlet of a safety or relief valve provides these advantages not otherwise attainable . . .



- Isolates valve from product contamination.
- No product loss as long as the rupture disc remains intact.
- Process or product may be changed without varying valve design or construction.
- Overpressure relief is instant, reaching the valve through wide open, unrestricted orifice.
- Eliminates shut-down time during normal operation.
- Bottle-tight seal during normal operation assures no loss of product.

The absence of a BS&B Safety Head may mean a change of valve construction when process or product is modified. However, with valve mounted above a BS&B Quik-Sert Safety Head the same valve may be used for varying services without alteration. You save the cost of additional equipment. You save the cost of time-consuming valve changes.

If you have a corrosion and plugging problem with your relief valves, call your nearest BS&B Safety Head sales center now. Or write to . . .

BLACK, SIVALLS & BRYSON, INC.

Safety Head Division
Dept. 2-F6
7500 East 12th Street
Kansas City, Missouri

Happenings . . .

rently available meets all requirements of today's auto engines.

• Quality improvements formerly absorbed by refiners are no longer feasible because cost of units needed for further antiknock quality are prohibitive.

• Auto buying trends are swinging to the small economy car.

Standard rocket scientist Wayne Proell says there will be trend to fewer missle types that must be ready to fire on an instant's notice. He said there will be wider development and use of specialized solid fuels to replace the tricky liquid ones.

New Industrial Polyurethane Thermoplastic Elastomer

Development of a new polyurethane thermoplastic elastomer for industrial applications has been announced by B. F. Goodrich Chemical Co. It reportedly has extremely high tensile strength at high ultimate elongation; also, excellent solvent resistance, particularly to gasoline, low air permeability and outstanding abrasion resistance. The material is available in tough, rubbery clear-amber granules which convert into end products by milling, calendering, extrusion, or molding. First major application is expected in wire and cable jacketing. Other potential uses include: fuel hose, small-bore tubing, belting, coated fabrics, sheeting for equipment liners, engine mounts, valve diaphragms, pump components, and insulators.

Chlorine Is Said to Be Ruining Redwood Towers

The deterioration of redwood cooling towers has reportedly been traced to using chlorine as an algaecide. An eight-year study by California Redwood Association has been confirmed by the Forest Products Research Laboratory, Great Britain and the U.S. Forest Products Laboratory. Alkalinity, when combined with chlorine, rapidly delignifies the wood, says the report. Use of a non-oxydizing algaecide reportedly eliminates such deterioration. Cooling Tower Institute is said to be preparing a similar report to be released within a month.

Urges That Foremen Serve As Communications Medium

The oil industry's supervisory force should be developed into an enthusiastic medium for communicating to its employes that political and economic measures harmful to the industry jeopardize their jobs, according to Millard E. Stone, vice president, industrial relations, Sinclair Oil Co. Speaking at a NPA meeting, he said ". . . the working man should take a look at his union, company and industry and try to determine whether his leaders have perhaps been helping to price what he makes out of the market." He added that the "supervisor or foreman is just about all the 'management'

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extend high pressure systems *without* interrupting service!

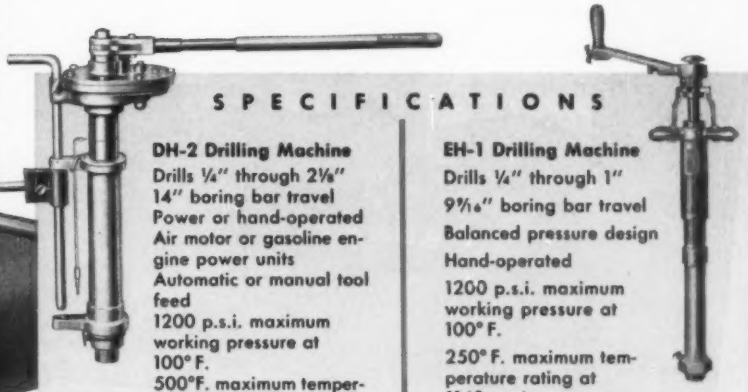
use **MUELLER**®
DH-2 or EH-1 drilling machines

Just a few simple steps are all that is needed to add a line to your high pressure air, steam, water, gas, crude or refined oil or chemical piping systems when you use the Mueller DH-2 or EH-1 Drilling Machine.

Lateral lines are added quickly and safely under completely controlled conditions. Service to other parts of your plant or refinery are not interrupted while the tie-in is being made.

At left is shown the power-operated DH-2 Machine attached to a Mueller Curb Valve Tee and drilling into a high pressure line. A variety of Mueller No-Blo Fittings are available for use with either the "DH-2" or "EH-1" machines.

Write for complete information.



SPECIFICATIONS

DH-2 Drilling Machine
Drills ¼" through 2⅛"
14" boring bar travel
Power or hand-operated
Air motor or gasoline engine power units
Automatic or manual tool feed
1200 p.s.i. maximum working pressure at 100° F.
500°F. maximum temperature rating at 1,000 p.s.i.

EH-1 Drilling Machine
Drills ¼" through 1"
9⅞₁₆" boring bar travel
Balanced pressure design
Hand-operated
1200 p.s.i. maximum working pressure at 100° F.
250° F. maximum temperature rating at 1140 p.s.i.

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MUELLER CO. since 1857 SERVING the Natural Gas Industry QUALITY

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Factories at: Decatur, Chattanooga, Los Angeles;
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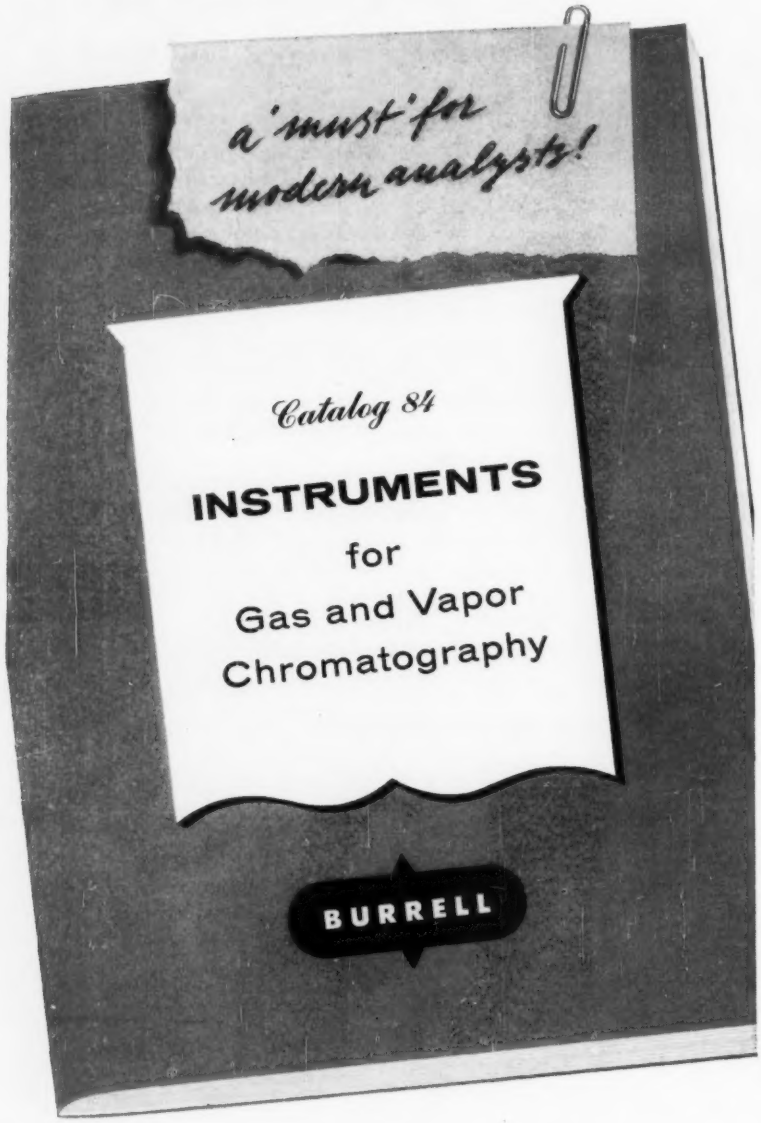
"For Scientists Everywhere"

Important new booklet

Now, for the first time in the dynamic history of modern chromatographic analysis, you can have a complete listing of instruments and accessories in one handy volume.



Only Burrell builds a complete series of laboratory instruments for chromatographic analysis, including four models of the versatile Burrell Kromo-Tog for research or process control.

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Happenings . . .

the rank-and-file employe ever encounters with any regularity." He urged that oil direct employe and public attention to the fact that "oil profits are not excessive, a huge investment is required for just one job in the industry, and that only further inflation will spring from the 'purchasing power,' 'cost of living,' and 'productivity' approaches to wage determination."

Japanese Oil Industry to Push Expansion Program

The Japanese oil industry plans to spend $1.1 million on long range expansion and modernization extending through 1967. Current crude refining capacity of 500,000 bpd is expected to be increased to 785,000 bpd by 1962, and to 1.6 million bpd by 1975. Some have criticized the plan because Japanese refineries are currently running at only 65 percent of capacity. However, industry sources say the budget is necessary to modernize old equipment and save refining losses, and to meet increasing demand.

– Changing Times –

Western Oil and Fuel Co. and International Refineries, Inc. will become part of Continental Oil Co., subject to stockholder approval. Brand names and management would not change.

Monsanto's Chemical Co.'s Lion Oil Co. refinery has completed **three-million man hours without a lost-time accident.**

Venezuela is maintaining a consulate in Dallas, 1309 Main St., Room 914-15. Offices are open from 10-3, Mon. through Fri.

Sun Chemical Co.'s subsidiary, **Warwick Wax Co., Inc., has been acquired by Western Petrochemical Corp. in straight cash transaction.** Company has refineries at Chanute and Coffeyville, Kan., and Gramercy, La.

The 71,282-ton "Princess Sophie," said to be the biggest merchant ship ever built in U.S., went into service recently. Queen of Greek merchant marine, Sophie is 859 feet long.

The Fluor Corp., Ltd. has sold its subsidiary, **Midwest Metals, Inc. to Hydrometals, Inc.,** New York. Company **also bought majority interest in Dutch Engineering firm** and set up new subsidiary—Fluor Schuytvlot, N.V., Holland.

Gulf Oil Corp.'s Refinery Technology laboratory at Philadelphia **has become division of Gulf Research & Development Co.,** Harmarville, Pa. Lab will not change location.

President Eisenhower has exempted all overland imports of oil from mandatory controls. Move opens import door for Canada and Mexico.

Ford Motor Co. has developed **unique supercharged gas turbine engine of 300 horsepower.** It has been under development 2½ years—weighs only one-fourth that of truck diesel engine of comparable

For more data on advertised products, use Readers' Service Cards, last page.

Ideco's portable H-40 Dual Rambler drilling rigs are credited with reducing the well completion time for Y.P.F. Argentina from 45 days to an average of 15 days. Yes, these dual trailer units really save time, and they withstand years of rugged field service. One example of the special features which assure long-life service from Ideco rigs is protection from corrosion.

The ten H-40's shipped from the U.S.A. to Y.P.F. were given the best corrosion prevention treatment available. Each unit was completely zinc coated, by hot-dip galvanizing or metallizing, at the Nowery J. Smith Co. Large structural parts not suitable for hot-dip galvanizing, because of size or dimensional stability requirements, were protected with special metal spray treatments by competent craftsmen. This extra protection means that Y.P.F. will get better than good service from its Ideco rigs for many years without fear of breakdown due to corrosion.

If corrosion is a factor in the work-life of your equipment, think Nowery J. Smith Co. Think Nowery J. Smith Co. for Hot-Dip Galvanizing • Metallizing • Pickling • Sand Blasting • Painting • Plastic Applications.

LARGEST HOT-DIP GALVANIZERS IN THE SOUTHWEST

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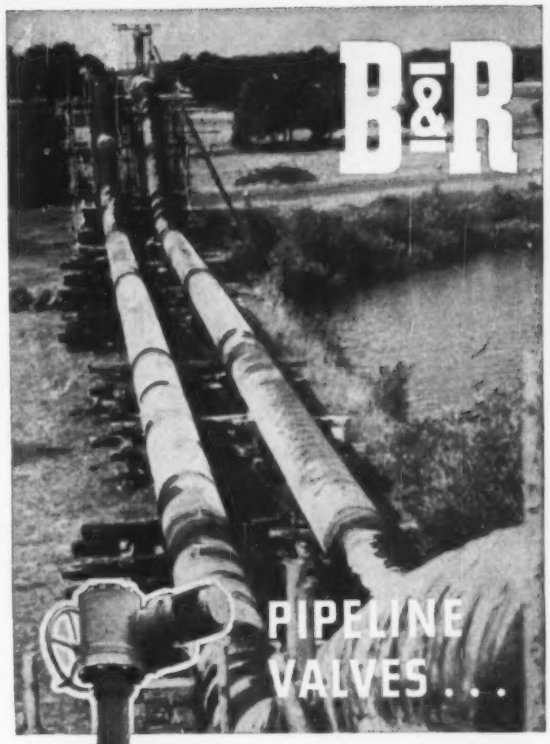
One of the Smith Industries —



. . . produced by BOPP & REUTHER are in use in the 24" and 28" pipelines running from Wilhelmshaven to Cologne and from Rotterdam to Cologne. The biggest pipeline of the Arabian Peninsula will have 30" valves made by BOPP & REUTHER.

Please consult our pipeline engineers.

B&R GATE VALVES
for pipelines

Oe 775 e

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AMOCO CHEMICALS—A NEW RESOURCE

Grease Thickener 0578 is a preformed, nonsoap, all organic gelling agent unlike any other thickener. It is a free-flowing, dust-free, granular material that is easy to handle and work with. Grease Thickener 0578 can be readily dispersed in oil to make greases by heating, cooling and colloid-milling. This thickener—an Amoco Chemicals exclusive—is now being trial marketed.

A dropping point of 480° F. is typical for No. 2 greases formulated with Amoco's new Grease Thickener 0578.

Using Grease Thickener 0578, grease compounders can offer products for both industrial and automotive lubrication that have the widest possible performance range. NLGI No. 2 greases can be formulated with an ASTM dropping point of 480° F.—at least 100 degrees higher than conventional lithium soap greases. And greases so formulated have demonstrated superior mechanical, thermal, and oxidation stability. They are water resistant and are not readily susceptible to oil leakage.

The full story on Grease Thickener 0578, together with technical assistance in formulating greases using it, is yours. Your inquiry will receive immediate attention.

AMOCO CHEMICALS

AMOCO CHEMICALS CORPORATION

910 South Michigan Ave., Chicago 80, Illinois

– Changing Times –

horsepower. **Fuel economy is said to rival a diesel and be superior to conventional gasoline engines** under most operating conditions.

Continental Oil Co. will lease Malco Refining Co.'s Artesia, N.M., refinery. Newly formed Continental subsidiary will serve Malco customers.

Shell's 8,500 union-represented workers plan to join in pension fund bargaining. OCAW says this is first time unions in Shell plants had agreed to joint action.

Triangle Refineries Corp., Houston, Kerr-McGee Oil Industries subsidiary, **has purchased Cotton Valley Solvents Corp.** A 2,000-bpd refinery near Shreveport is included in deal.

First British Petroleum Co. Tanker to sail up St. Lawrence River has landed at Montreal. She is "British Freedom," carrying 16,000 tons of crude oil.

American Oil Co. has sold its Destrahan, La., refinery to Brill Equipment Co. The 37,500-bpd refinery was completely rebuilt between 1950-53. Purchase includes 3-million-barrel tank farm, grease plant, canning plant and boiler plant.

Texas-U.S. Chemical Co. will move its headquarters from New York to Port Neches, Texas, this month. Small group of employes are involved.

Shell Oil Co.'s oil burner laboratory at Sewaren, N.J., will move to expanding facilities at Shell's Wood River laboratory during July.

Gulf Oil Corp. will move its Manufacturing department from Pittsburgh to Houston this month. Seven key employes are involved.

Gas utility and pipe line industry, which has 650 million in natural gas storage facilities to meet peak demands of its 32 million customers, **has boosted underground reservoir capacity to 2.7 trillion cubic feet,** says AGA.

Tulsa office of American Cyanamid Co.'s Refinery Chemicals department has moved to 101 Shell Building, 18th and Baltimore.

Arkansas Louisiana Chemical Corp. plans to begin marketing gasoline on retail basis. Stations will be built in Arkansas, East Texas and Louisiana.

Armour Research Foundation has begun diversified research program on effect of radiation on petroleum and petrochemical processing. Standard Oil Co. (Ind.) will sponsor the project.

Montecatini Co. reports it will be selling polypropylene on commercial market by 1959.

Arabian American Oil Co. has received National Safety Council's Award of Honor, its highest recognition, for outstanding safety achievement during 1958. **Company had frequency rate of 3.1** disabling injuries for each million man-hours worked.

Pauley Petroleum, Inc., has acquired Newhall Refining Co.'s 3,000-bpd skimming and asphalt plant just South of Newhall, Calif.

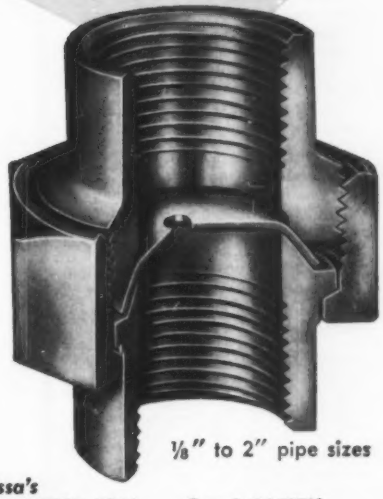
here's real **ECONOMY...**
time-saving **SIMPLICITY...**
and sure-fire **DEPENDABILITY**

for metering, measuring, controlling any piped material!

this Catawissa Cup-Orifice Plate will convert any standard Catawissa Union into a...

GASKETLESS ORIFICE UNION

- ELIMINATES *the necessity of expensive gaskets!*
- ELIMINATES *the uncertainty of what type gaskets are needed for specific temperature and pressure requirements!*
- ELIMINATES *fumbling for extra parts!*



all this PLUS

⅛" to 2" pipe sizes

Catawissa's exclusive PERFECT SEAL . . . 3-to-1 SAFETY FACTOR — and GUARANTEE of complete satisfaction!

Orifice Union problems of the past are gone forever! Stainless or carbon steel cup-orifice plate (blank or drilled) easily, quickly, securely fits into place between union head and tail pieces to form a good, tight, leakproof seal! Temperature and pressure requirements are restricted only by the rating of the union itself (3000-lb. service, 9000-lb. test)!

Just specify *"Catawissa Cup-Orifice Plates"* or *"Catawissa Cup-Orifice Unions"* at your favorite supply store— or write direct for catalog and complete information.

UNION SPECIALISTS for 1917 **42** 1959 years

CATAWISSA VALVE & FITTINGS CO.
CATAWISSA • PENNSYLVANIA

CRUSHPROOF
LEAKPROOF
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STAINLESS STEEL LINED
FOR VOLATILES...CHEMICALS

Stands pressures up to 200 psi . . . rubber covered and leakproofed with special packing. Safe, sure protection for conveying the most volatile of chemicals and liquids without discoloration, contamination or corrosion. Ideal for handling solvents, special chemicals, high octane gasolines and jet fuels.

It is lighter in weight than any comparable competitive hose . . . easy to handle with swivel flange that allows installation in any position without turning entire hose to meet bolt holes. Available in sizes 2" to 12" I.D. Write for full details to Pennsylvania Flexible Metallic Tubing Co., Inc., 7207 Powers Lane, Philadelphia 42, Pa.

NEW BOOK

Gives complete technical details on flexible tubing. Free copy for you.

PENFLEX
TIGHT AS A PIPE BUT...
FLEXIBLE

Meetings Calendar

June	
17–18	**American Society of Mechanical Engineers,** Engineering Management Conference, Statler Hilton Hotel, Los Angeles.
21–26	**American Institute of Electrical Engineers,** Summer and Pacific General Meeting, Olympia Hotel, Cleveland.
21–26	**American Society for Testing Materials,** Annual Meeting Chalfonte-Hadden Hall, Atlantic City.
21–26	**Air Pollution Control Association,** Annual Meeting, Statler Hotel, Los Angeles.
22–26	**National Association of Corrosion Engineers,** Corrosion Control and Reaction Intermediate Level Short Course, Massachusetts Institute of Technology.
24–25	**Western Petroleum Refiners Association,** Mid-Continent Technical-Industrial Relations Meeting, Broadview Hotel, Wichita.
24–26	**American Association of Cost Engineers,** Carnegie Institute of Technology Campus, Pittsburgh.
Aug.	
10–13	**Society of Automotive Engineers,** National West Coast Meeting, Hotel Georgia, Vancouver, B.C.
23–26	**American Institute of Electrical Engineers,** Petroleum Industry Electrical Conference, Wilton Hotel, Long Beach, Calif.
Sept.	
2– 4	**Cryogenic Engineering Conference,** University of California, Berkeley.
9–10	**ASME,** International Congress on Air Pollution, New York.
13–18	**American Chemical Society,** National Meeting, Atlantic City.
16–18	**National Petroleum Association,** Annual Meeting, Traymore Hotel, Atlantic City.
17–	**Natural Gasoline Association of America,** Rocky Mountain Regional Meeting, Casper Wyo. or Calgary, Alberta.
20–23	**ASME,** Petroleum Mechanical Engineering Conference, Rice Hotel, Houston.
21–25	**ISA,** Annual Instrumentation-Automation Conference and Exhibit, International Amphitheater, Chicago.
22–24	**Industrial Nuclear Technology Conference,** Morrison Hotel, Chicago.
23–24	**WPRA,** Rocky Mountain Technical-Industrial Relations Meeting, Henning Hotel, Casper.
27–30	**AIChE** Meeting, Hotel St. Paul, St. Paul.
28–30	**American Oil Chemists Society Meeting,** Hotel Statler, Los Angeles.
29–30	**WPRA,** Management Seminar, Western Hills Hotel, Wagoner, Okla.
28-Oct 1	**American Welding Society,** Fall Meeting, Sheraton-Cadillac Hotel, Detroit.
29-Oct 1	**NACE,** Western Region Conference, Bakersfield Inn, Bakersfield, Calif.
Oct.	
5– 8	**NACE,** Northeast Region Conference, Lord Baltimore Hotel, Baltimore, Md.
7– 8	**WPRA,** Annual Stream Pollution and Waste Disposal Conference, Broadview Hotel, Wichita.
8– 9	**California Natural Gasoline Association,** Fall Meeting, Huntington-Sheraton Hotel, Pasadena, Calif.
12–14	**National Electronics Conference,** Hotel Sherman, Chicago.
16–	**NGAA,** Southern Regional Meeting, Carlton Hotel, Tyler, Texas.
20–22	**American Standards Association,** National Conference on Standards, Sheraton-Cadillac Hotel, Detroit.
20–22	**NACE,** North Central Region Conference, Cleveland.
26–28	**National Lubricating Grease Institute,** Annual Meeting, Roosevelt Hotel, New Orleans.
28–29	**Computer Applications Symposium,** Morriston Hotel, Chicago.
28–29	**WPRA,** Question and Answer Session on Refining Technology, Rufus Garrett Hotel, El Dorado, Ark.
28–30	**Society of Automotive Engineers,** National Fuels and Lubricants Meeting, La Salle Hotel, Chicago.
Nov.	
4– 6	**Institute of Radio Engineers,** National Automatic Control Conference, Sheraton Hotel, Dallas.
9–11	**API,** Annual Meeting, Conrad Hilton, Palmer House, and Congress Hotels, Chicago.
16–20	**International Automation Exposition and Congress,** New York Trade Show Building, New York.
17–18	**WPRA,** Computer Conference.
20–	**NGAA,** Panhandle-Plains Regional Meeting, Herring Hotel, Amarillo.
29-Dec4	**ASME,** Annual Meeting, Chalfonte Haddon Hall, Atlantic City.

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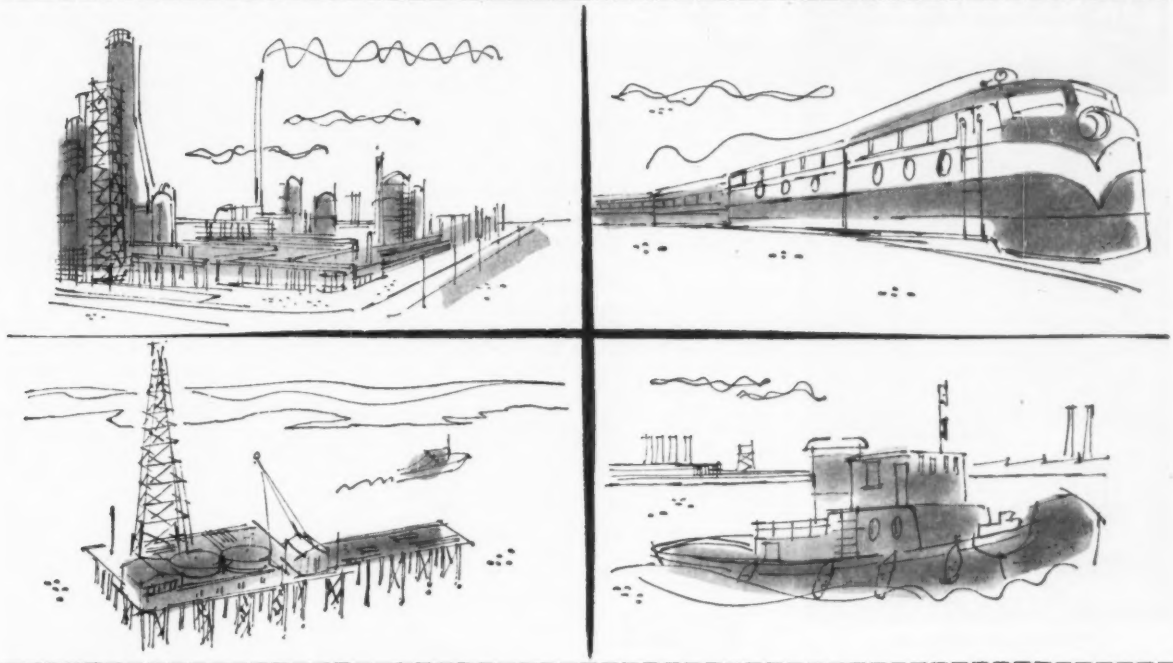

it's KOPPERS Piston Rings

Where profit depends on keeping equipment in service, engineers recognize the importance of ring performance. That is why Koppers Piston Rings go into the finest engines in the world . . . why they are selected for replacement when better performance is demanded.

Since the first diesel engine, Koppers has produced piston rings of predictable performance in a complete range of materials and a wide selection of types and sizes. If you have a ring problem, Koppers can offer you the benefit of their experience. Write to: KOPPERS COMPANY, INC., Piston and Sealing Ring Department, 4906 Hamburg Street, Baltimore 3, Maryland.

Send now for Koppers recommended Piston Ring Set-Ups applicable to the engines which you operate.

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PISTON AND SEALING RINGS

Engineered Products Sold with ***Service***

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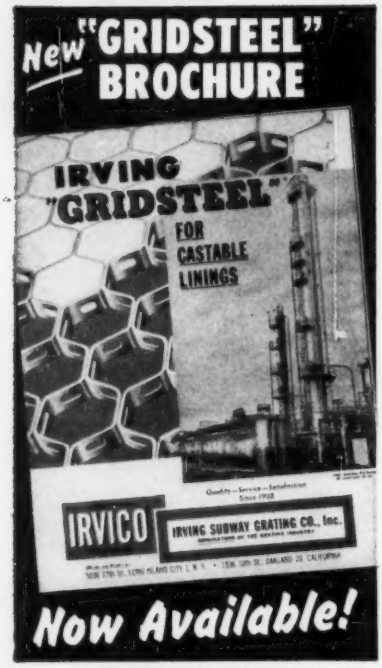
DISCOVER HOW!

To reduce Shutdowns with "Gridsteel"



Gridsteel reduces shutdown time for repairs of fire-clay linings in refractory units when used to armor castables.

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IRVING SUBWAY GRATING CO., Inc.
5054 27th ST., LONG ISLAND CITY, N. Y.

Please send me your "Gridsteel for Castable Linings" Catalog.

Name.....Title.....

Company.....

Address.....

"A Fitting Grating for Every Purpose"

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IRVING SUBWAY GRATING CO., Inc.
Originators of the Grating Industry

Offices and Plants at
5090 27th St., LONG ISLAND CITY 1, N. Y.
1890 10th St., OAKLAND 23, CALIFORNIA

New Books...

New Hydraulic Standards

"Standards of Hydraulic Institute, 10th Institute, 10th Edition," has available insertions on colored paper to be placed in the original loose-leaf cover. Some of the important changes include dimensions of NEMA type C face-mounted motors; NPSH charts for centrifugal hot water pumps, single and double suction; revisions in the test code for centrifugal pumps, and calculation of volumetric efficiency of reciprocating pumps, using compressibility factors for water and for hydrocarbons.

(Hydraulic Institute, *Standards of the Hydraulic Institute, 10th Edition (Revision)*, Hydraulic Institute, 122 East 42nd St., New York 17, N.Y., $1.25.)

Alaskan Crude Analyses

"Analyses of Some Crude Oils from Alaska" (Report of Investigation 5447), published by the Bureau of Mines, provides detailed analyses of 20 crude-oil samples collected in recent years from five areas of Alaska's arctic slope. The samples were from oil and gas wells in the Barrow Lakes, Umiat, Cape Simpson, Fish Creek, and Wolf Creek areas and exhibit wide variations, both chemically and physically.

(Bureau of Mines, *Analyses of Some Crude Oils from Alaska, Report of Investigation 5447*, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C., $.25.)

What's in Standardization?

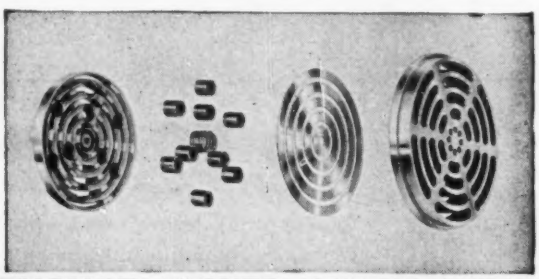
"Standardization — What's In It for Me?", contains messages from the chemical and petroleum industries—the printed proceedings of the Ninth National Conference on Standards, held in 1958. The book is published by ASA, sponsor of the conference. Authoritives from the chemical and petroleum industries are represented by a number of papers on safety labeling standards for hazardous substances. The fields they cover include the evolution of cautionary labeling, the need for uniform labeling laws and regulations, health hazards as related to precautionary labeling, and a review of legal responsibilities.

(ASA, *Standardization—What's In It for Me?*, American Standards Association, Department PR 58, 70 East 45th St., New York 17, N. Y., 128 pages, $4.50.)

Evaporation Loss Report

"Evaporation Loss in the Petroleum Industry—Causes and Control" contains up-to-the-minute suggestions and reports on methods to control evaporation loss. This new bulletin, (No. 2513) issued by API, covers sources of evaporation loss in all branches of the industry. Special emphasis is devoted to control of evaporation from tanks and during handling. The last half of the booklet contains equations, meterological data and tables of aid to those who select design and

VOSS VALVES in your machine mean



LESS MAINTENANCE, FEWER SHUTDOWNS for your compressor. (air, gas, ammonia)

- up to 40% more valve area • minimum pressure loss • higher efficiency
- less power consumption • normal discharge temperature
- quiet, vibration-free • utmost safety • lower operating costs

VOSS VALVES are made to specification, machined from solid stock (not cast)—using best alloy steels; for corrosion condition—stainless steels, such as 410, 18-8 or non-ferrous alloys—monel, inconel, etc. PLATES are machined (not stamped) and ground for precise close tolerance fit; are dimensionally stable . . . ductile . . . resist fracture, high temperatures and corrosion . . . withstand fatigue. SPRINGS of heavy rectangular sections and large diameters, add to dependability and safety.

Our detailed proposal will be sent without obligation. Send name, bore, stroke and speed of machine.

J. H. H. VOSS VALVES REG. U.S. PAT. OFF.

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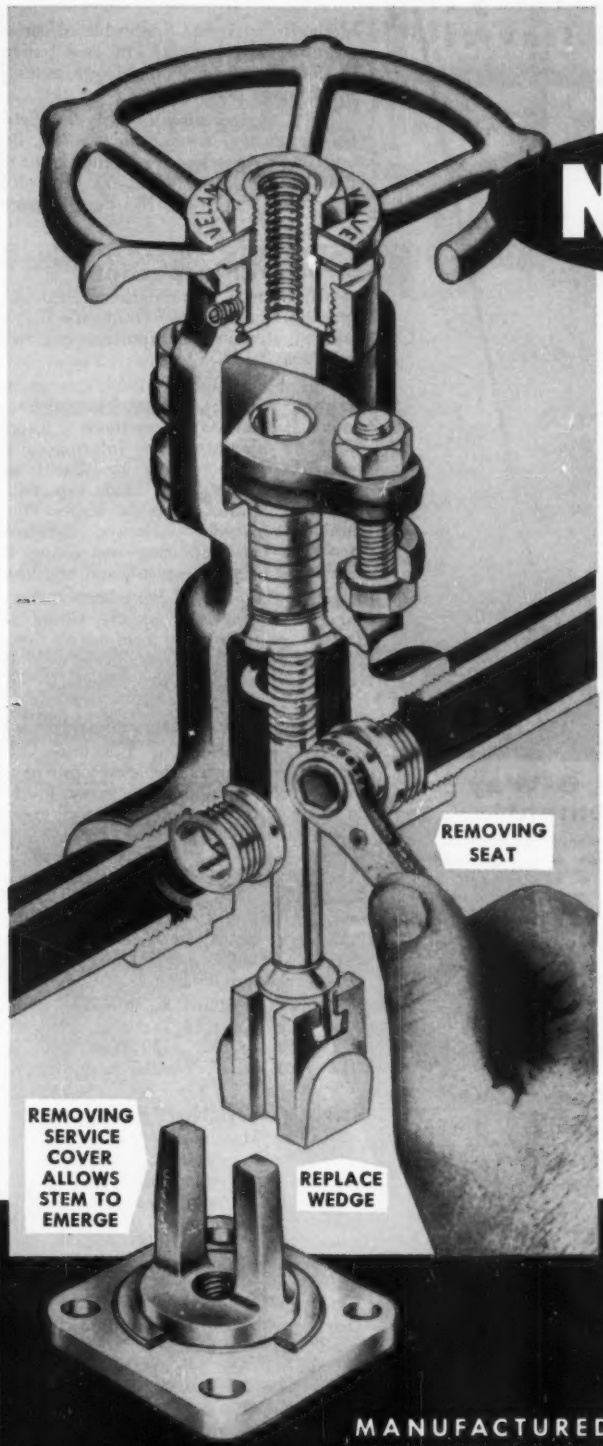


INTRODUCING THE

NEW VELAN

BONNETLESS
FORGED STEEL
GATE VALVE

1 Velan Valves will stay in the line at least twice as long as standard gate valves under same operating conditions. The valve does the work of 2 valves and provides double-block bleed.

2 Only Velan Valves can be readily tested for tightness of both seats and are guaranteed for impenetrable tightness from both sides.

3 Drop forged one-piece bonnetless design eliminates conventional body bonnet gasket leakage and assures perfect alignment of all working parts.

4 Only Velan Valves can be cleaned or flushed in the line under full pressure or during shut-down resulting in longer valve life and increased production.

5 Only Velan Valves can be tested for tightness in line under full pressure during shut-down.

6 Positive and smooth guiding of wedge with very little clearance eliminates drag and wear on seating faces during closing and opening of valve.

7 Inexpensive guide cover can be replaced to provide new positive guiding of wedge.

8 Valve is not easily damaged due to excessive torque when using extension wrenches.

9 Hardened (or Stellited) ground lapped seats resists better corrosion.

10 Slightly damaged seating faces on seats can be easily relapped in the lines.

11 Easily replaceable screwed-in seats, fully interchangeable for the first time in any Gate valve.

12 Wedge can easily be removed in the line.

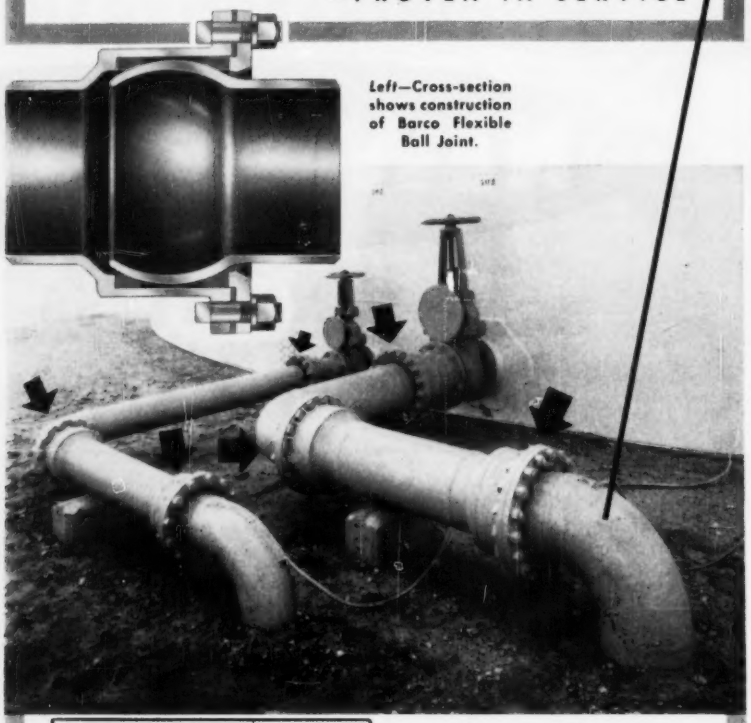
13 Positive backseat isolates stuffing box from line pressure and enables repacking under pressure.

MANUFACTURED

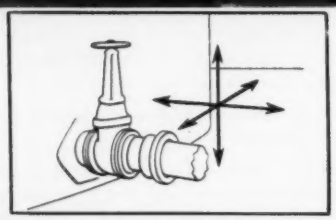
IN U.S.A. AND CANADA BY VELAN VALVE CORP.
PLATTSBURG, N.Y., MONTREAL, CANADA

IN GREAT BRITAIN BY NEWMAN, HENDER & CO. LTD.
WOODCHESTER, STROUD, GLOS.

Unlimited Flexibility!
—PROVEN IN SERVICE



Left—Cross-section shows construction of Barco Flexible Ball Joint.



Allows 6-Way Movement!

Freedom of movement in any direction is readily possible with these ball joint connections of 12" pipe (right) and 8" pipe (left) to 80,203 bbl. tank shown in above photo. (Photo: SHELL OIL COMPANY, Dominguez Refinery, Wilmington, Calif.)

Barco Ball Joints—*Fire Safe!*

provide complete protection against FIRE, PIPE EXPANSION, TANK SETTLING

Major oil companies throughout the country now approve the use of Barco's new large size Flexible Ball Joints on tank connections for the following reasons:

1. Fire-safe. The joints have passed rigid fire and water spray tests.
2. Superior for handling pipe expansion—no combustible packing, no thin wall sections, no "end thrust" from pressure, no heavy pipe anchoring required.
3. Complete protection—relieve strain and twisting forces on valve flanges or tank wall.
4. Compact! Ideal for use inside narrow space between fire wall and tank. Easy to design piping for any amount of flexibility desired.
5. Also useful for insulating piping against electrolysis.
6. Long service life without maintenance. No lubrication. Sizes to 16"; flanged or welding ends.

For engineering recommendations, see your nearest Barco representative or write. ASK FOR CATALOG 215B and BULLETIN 31-A.

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BARCO MANUFACTURING CO.
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The Only Truly Complete Line of Flexible Ball, Swivel, Swing and Revolving Joints
In Canada: The Holden Co., Ltd., Montreal

Books . . .

methods for control applicable to various parts of the continent. This new bulletin is the second in its proposed series of preliminary publications.

(API, *Evaporation Loss in the Petroleum Industry—Causes and Control, Bulletin 2513,* American Petroleum Institute, Publications Department, 50 West 50th St., New York 20, N. Y., 59 pages, $1.50.)

Structural Inspection

"Chapter 12, Foundations, Structures and Buildings," of the Guide for Inspection of Refinery Equipment, has been published by the API.

This First Edition, 1959, covers description of types, reasons for inspection, causes of deterioration, methods of inspection, and other inspection information on foundations for refinery equipment and structures of various kinds, including buildings. It also covers the inspection of ladders, stairways, walkways, platforms, structures for supporting and giving access to refinery equipment, and buildings.

(API, *Chapter 12, Foundations, Structures and Buildings, of the Guide for Inspection of Refinery Equipment,* American Petroleum Institute, 50 West 50th St., New York 20, N. Y., 19 pages, $1.00.)

Management Development

"Manager Selection, Education and Training", discusses the development of management personnel at every level—from front-line foremen to top executives. Written by an authority in the field, it provides help in starting a manager development program, and in appraising an existing program. The various phases of organizing and implementing the program are shown, and requirements of any type of office, department, or company are covered.

(Bennett, Willard E., *Manager Selection, Education and Training,* McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N. Y., 210 pages, $6.00.)

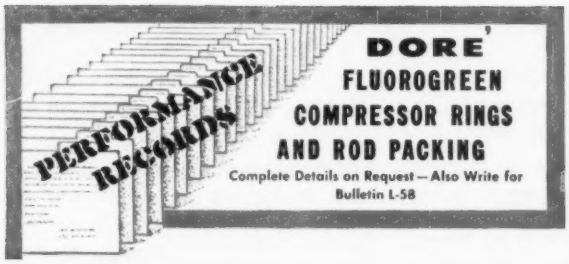
Rating Aviation Fuels

"ASTM Manual for Rating Aviation Fuels by Supercharge and Aviation Methods" gives complete instructions for the installation and operation of knock testing equipment for determining the knocking characteristics of aviation fuels for spark ignition aircraft engines. Two methods are covered:

- D 909, Method of Test for Knock Characteristics of Aviation Fuels by the Supercharge Method, covers the testing of fuels of 85 ASTM Supercharge octane number and over.
- D 614, Method of Test for Knock Characteristics of Aviation Fuels by the Aviation Method, covers testing of fuels of 70 ASTM Aviation octane number and over.

(ASTM, *ASTM Manual for Rating Aviation Fuels by Supercharge and Aviation Methods,* American Society for Testing Materials, 1916 Race St., Philadelphia 3, pa., 333 pages, $16.00.)

For more data on advertised products, use Readers' Service Cards, last page.



DORE' FLUOROGREEN COMPRESSOR RINGS AND ROD PACKING

Complete Details on Request—Also Write for Bulletin L-58

27 MONTHS' SERVICE WITHOUT CYLINDER WALL WEAR

This installation clearly demonstrates the extremely low coefficient of friction of Fluorogreen. After this long period of service, entirely without lubrication, the cylinder walls showed no measurable wear . . . no maintenance was required during the service period.

COMPRESSOR AND SERVICE DATA:

Bore	3-5/16"
Piston Speed	250 ft./min.
Pressure	229.7 psia Exhaust
Temperature	320 deg. F.
Product	Nitrogen, then Chlorine
Rings	3 FLUOROGREEN Compression rings with expander rings
Rod Packing	2 FLUOROGREEN rings per gland

Fluorogreen is John L. Dore' Company's registered trademark for their filled Teflon.

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DU PONT'S TEFLON HI-QUALITY NYLON

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Here's the most complete, most useful catalog on metering pumps ever published. Lets you select the exact unit you need to meet any requirement. Ask your Manzel field engineer . . . or write direct for YOUR FREE COPY.
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285 Babcock Street
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Specialists in metering pumps and lubricators since 1898.

"Let's do an abstract,' said the artist for the hundredth time.

"You pipe down," we answered, "and let us get on with selling Darlington Insulation."

"Pipes!" cried the artist. "Now insulated pipes can't help looking abstract. It's the shape they are. Anyway, there's nothing abstract about insulation that cuts heat loss to only 10%. You've said so yourself hundreds of times." So we let him do his abstract and here it is.

But we forced him to leave room for us to say that you will find Darlington Insulation saving money on pipes of all kinds—pipes for steam, for oil, and for many other basic materials of industry—all over the world. Our telephone number, if you'd like to know more, is NEWCASTLE 23666.

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Men In Industry...

Paul Siecke has been appointed general manager of Gulf Oil Corp.'s Cincinnati refinery, succeeding **Thomas F. Hogan** who has retired. **Latham J. Lashley** succeeds Siecke as director, process design, in the Pittsburgh office. Siecke joined Gulf in 1933 at the Port Arthur refinery, not long after earning his B.S. and M.S. degrees in chemical engineering at Texas A. and M. College. In 1939, he was transferred to the Pittsburgh general office and assigned to the Process division of what was then the Engineering and Construction department. Early in 1948, he was promoted to assistant to the chief process engineer. In 1950, when the Engineering and Construction department was established as a division of the Manufacturing department, Siecke became assistant to the manager of the division. In 1955, he was named director, process design.

Siecke

Lashley graduated from Tulane University in 1926. Shortly after graduation, he joined Gulf as a chemical engineer in the Test department, Port Arthur refinery. In 1932, he transferred to the general office in Pittsburgh as an engineer in the Process department. He was a section head in the Process Design division prior to becoming Siecke's successor.

Frank R. Shuman has been named manager of process development in Sun Oil Co.'s Research and Development division. He replaces **Earl M. Honeycutt** who recently became manager of manufacturing, polymers, for AviSun Corp.

Shuman started his career with Sun in 1943 as a chemical engineer in the Research and Development laboratory, Marcus Hook, Pa., refinery. He has supervised the construction and operation of pilot plants for hydrofluoric acid alkylation and wax refining. In 1953 he was named section chief for petrochemical processes and held this post prior to his new appointment. He attended Pennsylvania State University and graduated in 1942 with a B.S. degree in chemical engineering. He is a member of AIChE and ACS.

Paul E. Taliaferro has been elected president and chief executive officer of Sunray Mid-Continent Oil Co. Taliaferro succeeds **W. C. Whaley** who was named chairman of the executive committee. **C. H. Wright** was re-elected chairman, and **R. W. McDowell,** president of DX Sunray Oil Co., wholly owned subsidiary, was re-elected vice-chairman. All other officers were re-elected. Taliaferro joined Sunray in 1931 as general attorney and has served as a director of the company since 1946. He has been executive vice-president since 1952, and prior to that was general attorney, and vice-president assistant to the president.

Dr. A. Letcher Jones has been promoted to research supervisor, basic research, in the Chemical and Physical Research department, The Standard Oil Company (Ohio) at Cleveland. Since 1946, Dr. Jones has been with the company. He graduated from Hampden-Sydney College in 1936 and received his Ph.D. degree from the University of Virginia in 1943. He had been an instructor of chemistry and mathematics at Hampden-Sydney College and instructor of chemistry at Cornell before joining Sohio.

Jones

Walter A. Cronkright has been named a research chemist in the analytical group of The M. W. Kellogg Co.'s Research and Development laboratory, Jersey City, N. J. He was formerly with the General Chemical division, Allied Chemical and Dye Corp. and has just completed a tour of duty in the navy. He holds a B.S. degree in chemistry from Rutgers University and has taken graduate work for a M.S. degree at Drexel Institute of Technology, Philadelphia. He is a member of Pi Kappa Alpha Fraternity.

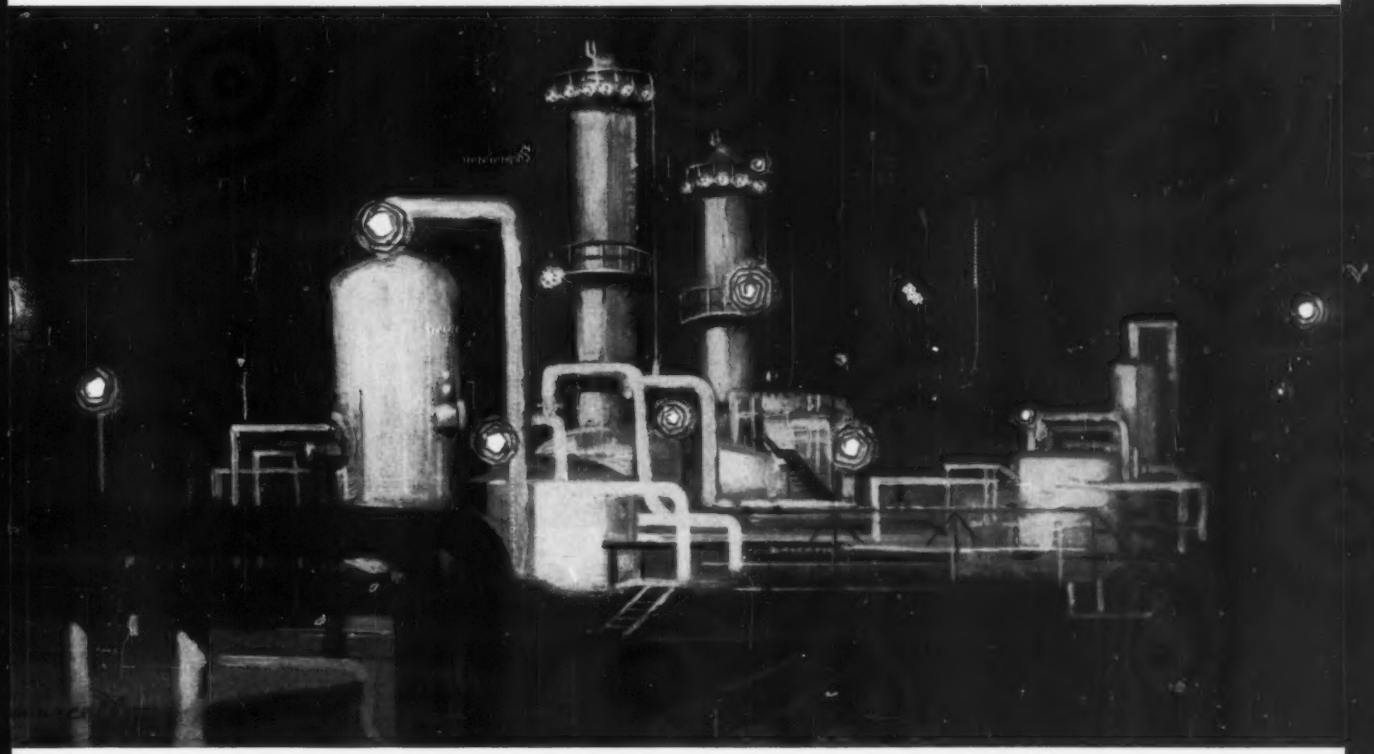
Winthrope C. Smith has been named a research associate by Esso Research and Engineering Co. A chemist in the firm's Technical Sales Service unit, he has been with Esso R&E 22 years. Most of his research work has been in development and applications of butyl rubber. Smith has a M.S. degree in chemistry from Pennsylvania State University, and a B.S. degree in chemistry from Washington and Lee University.

Dr. Robert C. Axtmann has been appointed to the Princeton University faculty as the first "Socony Mobil Professor" of chemical engineering for nuclear studies. He will be an associate professor in the school of engineering. The new chair is supported by Socony Mobil Oil Co., Inc. Dr. Axtmann has been with E. I. duPont de Nemours & Co. since 1950 as research physicist, nuclear reactor construction consultant, and research supervisor. He holds an A.B. degree from Oberlin College and M.A. and Ph.D. degrees from Johns Hopkins University. After working in low-temperature physics at the Aberdeen, Md., proving grounds, Dr. Axtmann joined Du Pont as a research physicist at the Argonne National Laboratory. In 1952, he was assigned as construction consultant to the Savannah River plant, Aiken, S. C., operated by Du Pont for the AEC.

W. B. Brown of Wichita, center, who has attended every Gas Measurement Short Course since they were started in 1924, is shown with officials of the 1959 course, held at the University of Oklahoma recently. With him are W. H. Carson, right, dean of the college of engineering and chairman of the executive committee of the short course, and R. F. Nowlin of Houston, general chairman of the 1959 course. Elected general chairman for the 1960 Short Course was R. R. McCafferty of Amarillo, general pipe line superintendent for Pioneer Natural Gas Co.

A refinery never sleeps

Twenty-four hours a day, a refinery is in operation. Its hundreds of miles of tubular products are constantly subjected to high temperatures and tremendous pressures. In order to survive under conditions like these, the tube must be hand-picked for the job. And, that's where National Tube comes in. If you need advice in refinery tube selections, get in touch with National Tube.



Our experience in this field comes from more than 60 years of gathering information for the solution of refinery tube problems. And, we've used this data to develop 24 different seamless steel tube analyses—each one the answer to a specific set of refinery conditions. Other chemical compositions are also available in tubular products, and a wide variety of high temperature problems are under study.

National Tube's Mill Service Force, available for field consultation, will be happy to help you find the right alloy, at the right price, to meet your needs. Write to National Tube Division, United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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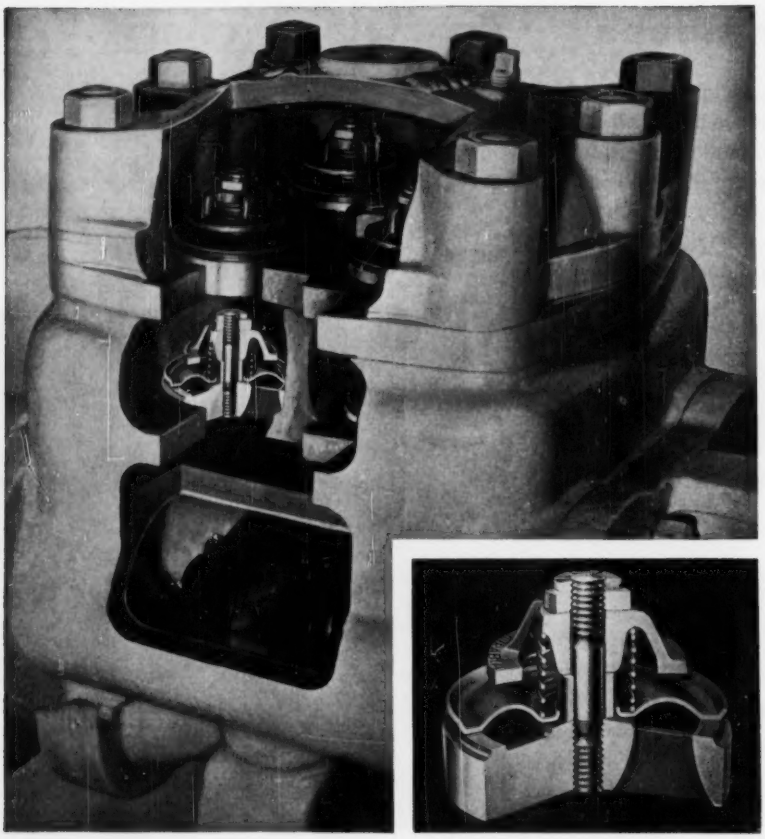
Here are National Tube's two dozen different tube analyses:

Carbon	5 Cr, ½ Mo	17 Cr
Carbon ½ Mo	5 Cr, ½ Mo, 1½ Si	18-8
1 Cr, ½ Mo	7 Cr, ½ Mo	18-8 Ti
1¼ Cr, ½ Mo	8 Cr, ½ Mo	18-8 Cb
2 Cr, ½ Mo	8 Cr, 1 Mo	18-8 Mo
2¼ Cr, 1 Mo	9 Cr, 1 Mo	25-20
2½ Cr, ½ Mo, ¾ Si	12 Cr	3½ Ni
3 Cr, 1 Mo	12 Cr, Al	5 Ni

"The world's largest and most experienced manufacturer of tubular products"

USS National Tube Division of United States Steel

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors
United States Steel Supply Division · United States Steel Export Company, New York



The valve for reciprocating pumps . . . old or new

Because they offer a happy combination of dependability, efficiency and extra life, DURABLA Valves are a credit to any reciprocating pump. Mechanically and metallurgically speaking, they will operate freely under temperature-pressure extremes, with highly corrosive fluids and in any position.

In a DURABLA Valve Unit, only "point contact" is made by the valve member on the sleeve, so it can't bind or hang-up. Due to its unique arched design, neither will it warp. The new V-7* taper-locked stud can be screwed down tight into the seat without any possibility of galling or breakage. And a self-locking nut and "drop-on" guard assure quick and easy inspection of working parts —without stud or seat removal.

Standard equipment on many new pumps, DURABLA Valve Units are also used throughout the world to re-valve older pumps. They come in fifteen sizes, designed to meet over 300 variations in installation requirements.

Write for new booklet PR69.

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114 Liberty Street, New York 6, New York

DURABLA®

DM-34

Men . . .

Later, he supervised work on reactors and was senior research adviser. In the past two years, he has been investigating the molecular structure of solvent extraction complexes and the nature of ionic equilibria. Dr. Axtmann is a member of ACS, American Physical Society, and Sigma Xi.

Glenn H. Curtis has been elected vice president of Stone & Webster Canada, Ltd. He joined the company in 1955 as engineering representative following five years' service with a Montreal construction company. He graduated from the University of Toronto in civil engineering in 1948 and received his M.S. degree in business administration from Harvard University in 1950.

Eugene T. Dotts has been named maintenance superintendent of SunOlin Chemical Co.'s urea plant, currently under construction. Dotts will be in charge of the maintenance of all equipment at the 73,000 ton-per-year urea plant, scheduled to be complete early in 1960. Meanwhile he will serve as field coordinator of construction for SunOlin. He began his career as a construction surveyor in 1951 at Sun's Marcus Hook, Pa. refinery. He later was named field engineer in construction, and zone engineer.

Dotts

C. Frank Corbin has been named comptroller and **Richard J. Hallinan** secretary of The Lummus Co. Corbin joined Lummus in 1955 and Hallinan joined the firm in 1958.

John C. Sample, a vice president, director and member of the Standard-Vacuum Oil Co. executive committee, has retired. Almost half of Sample's 39 years' service was in the Far East in sales, administrative and executive positions.

E. T. L. Borie has been named assistant superintendent of American Oil Co.'s Carteret, N. J., terminal. Formerly associate chemical engineer at Amoco's Destrehan refinery and more recently assigned to the Baltimore Automotive Research laboratory, Borie succeeds **E. W. Walker,** who has been named general superintendent of plants in the company's Atlanta region.

J. L. Lenker, currently vice president and a director of The British American Oil Co., Ltd., Toronto, Ont., has been elected a vice president of Gulf Oil Corp. **C. J. Guzzo,** who has been Gulf's vice president in charge of domestic marketing since 1954, has been designated a senior vice president. Both men will be headquartered in the general offices, Pittsburgh. Guzzo, as senior vice

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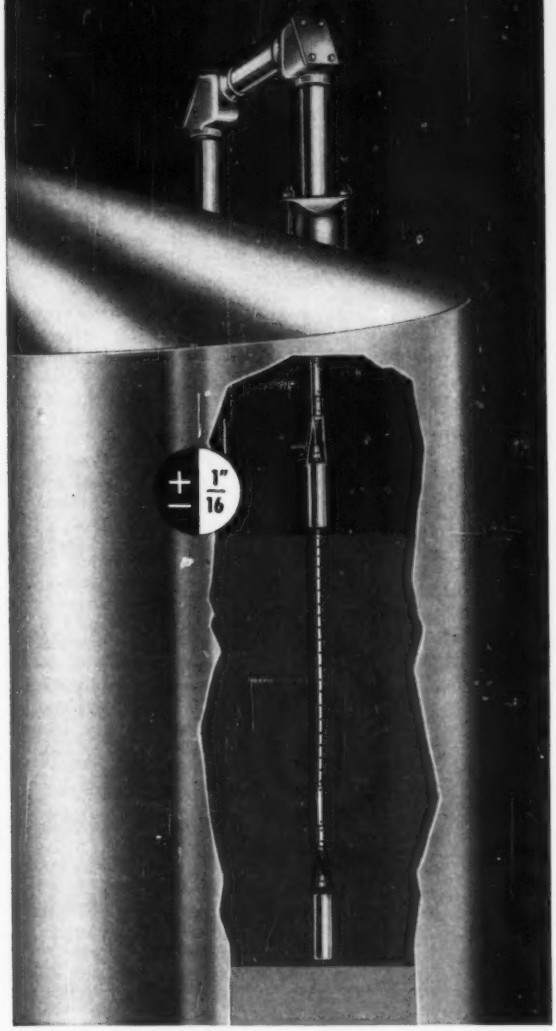
NOW COMPLETE AUTOMATION IN TANK GAUGING!



You can eliminate hand gauging completely with the new Gilbarco electronic Tank Gauge because this gauge measures *both product level and water interface*. At the turn of a switch the sensing element, which tracks product level, will penetrate the product to also measure water bottom. Readings of both levels can be made at the tank base or remotely on a Gilbarco Null-Balance Receiver. Gauges already installed can be equipped for this dual operation quickly, easily, inexpensively. Write for full information on the *only* gauge which gives you complete gauging automation.

Gilbarco

Gilbert & Barker Manufacturing Co.
West Springfield, Mass.
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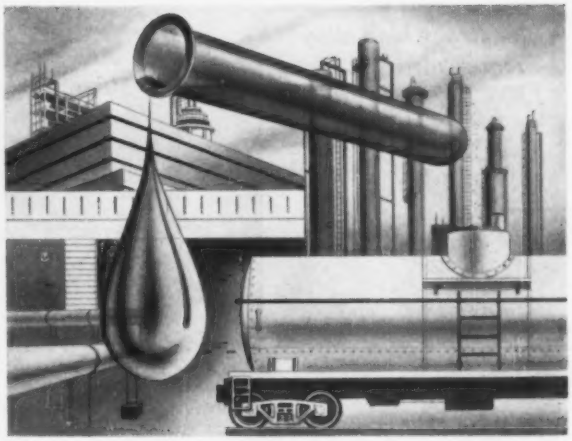

the PETROLEUM INDUSTRY and the WORLD PETROLEUM CONGRESS

During 100 years of progress, the Petroleum Industry has exceeded the fondest and most fanciful dreams of its founders. It must be recognized that in its growth, much credit is due to progressive management and to engineers, present and past, whose knowledge — courage — and pioneering spirit have brought about such vast production achievements.

The C. W. Nofsinger Company is proud to be associated, through its engineering services, with this vital enterprise and heartily wish for it a continued success.

In Engineering it's the People that Count

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Engineers and Contractors for the Petroleum and Chemical Industries

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GULF COAST—Russell G. Dressler, 204 Carolwood Dr., San Antonio 13, Tex.

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HOW TO BEAT THE HEAT

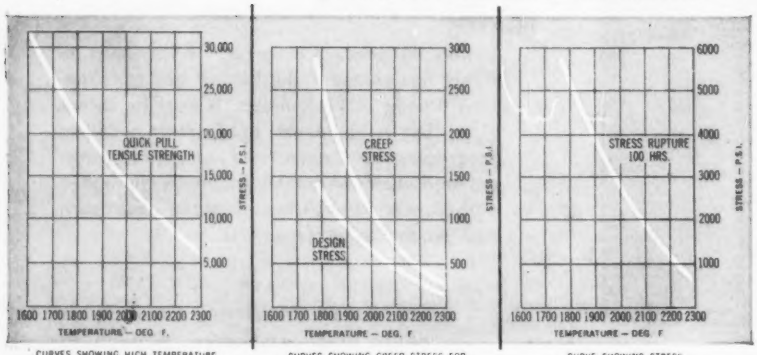
for strong high alloy requirements in the 1,800° to 2,300° F range!

DURALOY HOM*

*Covered by U.S. Patents

casting alloy

Duraloy "HOM" is a special high nickel alloy developed to produce castings that meet high temperature requirements, especially when castings are subject to oxidizing atmospheres.



CURVES SHOWING HIGH TEMPERATURE SHORT-TIME TENSILE STRENGTH OF DURALOY-HOM

CURVES SHOWING CREEP STRESS FOR CREEP RATE OF 1% IN 10,000 HOURS AND RECOMMENDED DESIGN STRESS FOR DURALOY-HOM

CURVE SHOWING STRESS TO RUPTURE AT 100 HOURS FOR DURALOY-HOM

Castings of DURALOY "HOM" are now being produced by our three methods: static, centrifugal and shell molded. Write today for additional information on this versatile new alloy.

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OFFICE AND PLANT: Scottdale, Pa.

EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.
ATLANTA OFFICE: 76—4th Street, N.W.
CHICAGO OFFICE: 332 South Michigan Avenue
DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.

Men . . .

president, will become a member of the company's executive group, consisting of the president, executive vice president and senior vice presidents.

Dr. Harvey E. W. Burnside has been named an engineering associate in Esso Research and Engineering Co. A member of the firm's Petroleum Development division, Dr. Burnside has been with Esso Research 21 years. His career began at the Esso Research laboratories in Baton Rouge, La., where the major part of his work consisted of engineering studies involved in the large scale pilot development of catalytic cracking. He joined the Linden laboratories in 1942 and has conducted studies on synthetic fuels and oil gasification for new uses.

He earned a Ph.D. degree in chemical engineering at M.I.T. and a B. S. degree at West Virginia University.

George A. Birrell has been appointed general counsel of Mobil International Oil Co. He succeeds **W. L. King,** who retired. After graduation from Yale University Law School in 1947, Birrell joined a New York law firm, of which he became a partner in 1956. For several years before he left the firm to join Socony Mobil in 1958, Birrell was concerned with Socony Mobil's international operations.

Franklin P. Frederick joined the firm of Bonner & Moore Engineering Associates on May 1. He was previously with Humble Oil & Refining Co. and Esso Standard Oil Co. While with these companies, he worked on operations research techniques and computer applications on problems of supply and distribution, inventory control, and gasoline blending. Frederick is a graduate of the Colorado School of Mines where he received a degree in petroleum refining.

Arthur W. Winter, assistant to the president of Great Northern Oil Co., has been named a vice president of the firm. Winter joined the firm in 1957. A native Minnesotan and graduate of Carleton College, he entered the refining industry in 1935 as a refinery chemist. He became president of Roosevelt Oil and Refining Co., Mt. Pleasant, Mich., in 1950.

Omar O. Juveland has been named a group leader at Whiting Research laboratories, Standard Oil Co. (Ind.). He will head a group of chemists in plastics research. Since he joined Standard in 1953, he has carried out laboratory investigations on new plastics. Dr. Juveland has a B.S. degree in chemistry from St. Olaf College and M.S. and Ph.D. degrees from the University of Chicago. He is a member of ACS, Phi Beta Kappa and Sigma Xi.

Richard H. Baldwin has been named a group leader at Whiting Research laboratories, Standard Oil Co. (Ind.). He will head design and process engineering group. Since he joined Standard, Baldwin has devoted much of his time to development in this area. He has a B.S.

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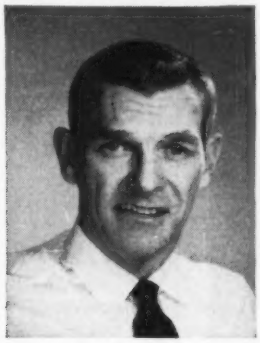
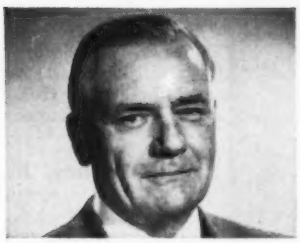
"I'm interested in boron trifluoride because it's an easy catalyst to work with" . . . Plant Superintendent



"I'm most interested in the high reactivity of boron trifluoride" . . . Research Director



"I've discovered that by using BF_3 we can simplify our plant designs" . . . Chief Engineer

What interests you most about Boron Trifluoride?

Whatever your reasons for investigating boron trifluoride, you'll find Baker & Adamson® is your best source of information. B&A has long been the leader in BF_3 research and production. B&A was the first to introduce boron fluoride etherate to industry . . . has shipped boron fluoride gas by tube trailer transport for many years—making it readily available in large commercial quantities. Today, B&A offers the widest range of BF_3 complexes, including ether, phenol, monoethylamine, other nitrogen and oxygen compounds. That's why—when it comes to BF_3 call on Baker & Adamson.

Useful product data bulletins

B&A has compiled extensive reference data on the use of boron fluoride gas and its complexes as efficient catalysts in organic synthesis. Boron fluoride's wide range of applications and its cost-cutting production advantages—such as its ease of catalyst removal—make it a factor to be considered in almost any organic synthesis problem. Write today for any or all of the free technical bulletins listed below:

TITLE	CODE No.
Boron Trifluoride, Compressed Gas	DA-34691
Boron Trifluoride, Compressed Gas Handling Information	TB-34691
Boron Fluoride Complexes with Nitrogenous Compounds	DA-3469-NIT-1
Boron Fluoride Complexes with Oxygen-Containing Compounds	DA-3469-OXY-1
Boron Trifluoride, Ether Complex, Tech.	DA-34711
Boron Trifluoride, Monoethylamine Complex, Tech.	DA-34661
Boron Trifluoride, Phenol Complex, Tech.	DA-34681

New book on Boron Fluoride

The most extensive study of boron fluoride to date is contained in a new book, "Boron Fluoride and its compounds as catalysts in organic chemistry," written by A. V. Topchiev, S. V. Zavgorodnii and Y. M. Paushkin. It discusses the use of boron fluoride as a catalyst in organic chemistry and also its derivatives and molecular compounds. Contents include physical and chemical properties; co-ordination compounds; compounds of boron fluoride in alkylation, polymerization, isomerization, cyclization, nitration and sulphonation reactions; condensation reactions in the presence of boron fluoride; and many other topics.

This book (price, $12) is published by Pergamon Press, Inc., 122 East 55th St., New York 22, N. Y.

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Allied Chemical

GENERAL CHEMICAL DIVISION

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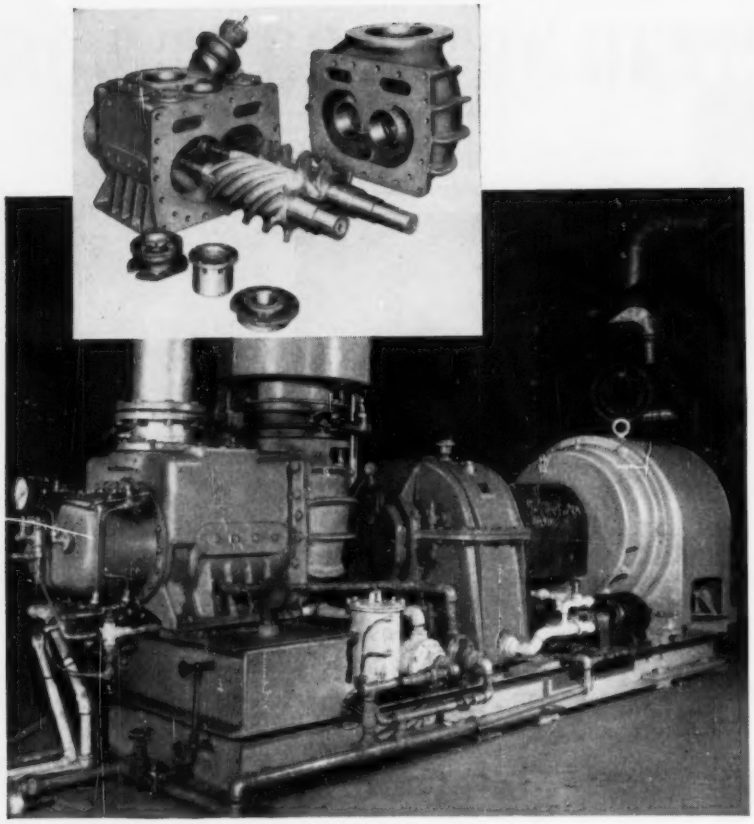


NEW *Fairbanks-Morse Positive Displacement Axial-Flow...*

Oil-Free Rotary Compressor

for pressure, vacuum or booster service!

Here is a mechanically-simple, precision-built, high-efficiency compressor that combines the best features of reciprocating and centrifugal designs!

The new Fairbanks-Morse Axial-Flow Rotary Compressor is a two-impeller helical-lobe type machine ...ideal for a wide variety of applications...smooth in performance, adaptable to any power source. Unit weights and space requirements are impressively low.

Standard models are available in single-stage units with capacities from 800 to 12,500 cfm. at compression ratios from 1.6:1 to 5.0:1—or in two-stage units with capacities from 2,000 to 12,500 cfm. at compression ratios above 5.0:1—and for booster service at maximum working pressures up to 250 psig.

Contact your nearby Fairbanks-Morse Branch, or write Fairbanks, Morse & Co., 600 So. Michigan Ave., Chicago 5, Ill.

Ask for new Bulletin ACO 100.1.

FAIRBANKS-MORSE

a name worth remembering when you want the BEST

COMPRESSORS · PUMPS · SCALES · DIESEL, DUAL FUEL AND GAS ENGINES
LOCOMOTIVES · ELECTRIC MOTORS · GENERATORS · MAGNETOS · HOME WATER SYSTEMS

Men . . .

degree in chemical engineering from Illinois Institute of Technology, where he also has worked toward a Ph.D. degree. He is a member of AIChE and Sigma Xi.

Henry W. Hinkle, comptroller of Phillips Petroleum Co., has been appointed a member of the Operating committees of Phillips Petroleum and Phillips Chemical Co. The committee analyzes proposals for new projects, substantial capital expenditures, and significant operating and policy changes prior to final Executive committee action on proposals it approves.

R. C. Brown, Calgary, Canada, has been elected a vice president and director of Continental Oil Co. He will be foreign representative for the Eastern hemisphere, with headquarters in London. Brown was formerly president and a director of Hudson's Bay Oil and Gas Co., Ltd., Continental's Canadian affiliate.

N. D. Jones, Jr., has been promoted to senior supervising engineer in the Technical division, Humble Oil & Refining Co.'s Baytown, Texas, refinery. He supervises a group of civil engineers who design refinery installations. Jones has a B.S. degree in civil engineering from Texas A&M College.

Dr. E. F. Voss, chief refinery engineer of Humble Oil & Gas Co., Houston, and **Dr. J. C. Geniesse,** director of the application research division of the research and development department of Atlantic Refining Co., Philadelphia, have received API Certificates of Appreciation. The presentations were made at the Refining division's traditional dinner May 28, dinner meeting.

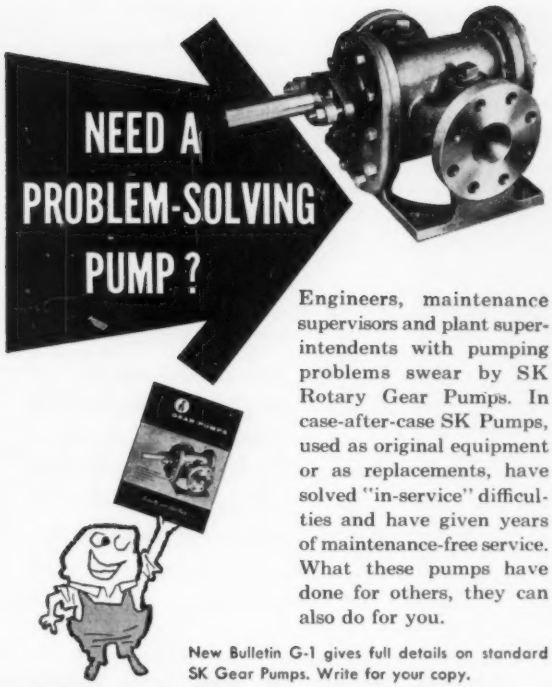
Edward J. Beetle has been promoted to manager of services at Gulf Oil Corp.'s Port Arthur refinery succeeding **Frank L. Bryan,** who has been transferred to the Manufacturing department headquarters in Houston as coordinator. **Bruce C. MacConnell** has been named director of accounting, Beetle's former position.

Beetle was first employed in 1927 at Philadelphia, Pa., by the Gulf Oil Burner Co., a former Gulf subsidiary. That same year he was transferred to the Philadelphia refinery as an Accounting department clerk.

George V. Myers has been elected executive vice president, Standard Oil Co. (Ind.) Formerly vice president for production, Myers joined Standard of Indiana as general manager of production in 1956.

Reimer E. Probst has been named a group leader by Standard Oil Co. (Ind.). He will be in charge of information research at Whiting Research laboratories. His group will survey, interpret, and evaluate information on scientific, technical, and commercial developments related to Standard's activities. Since he joined Standard in 1950, Dr. Probst has

For more data on advertised products, use Readers' Service Cards, last page.



Engineers, maintenance supervisors and plant superintendents with pumping problems swear by SK Rotary Gear Pumps. In case-after-case SK Pumps, used as original equipment or as replacements, have solved "in-service" difficulties and have given years of maintenance-free service. What these pumps have done for others, they can also do for you.

New Bulletin G-1 gives full details on standard SK Gear Pumps. Write for your copy.

Schutte and Koerting COMPANY

2257 STATE ROAD, CORNWELLS HEIGHTS, BUCKS COUNTY, PA.

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JET APPARATUS • ROTAMETERS • GEAR PUMPS • VALVES • HEAT EXCHANGERS

New! RACKS FOR MOUNTING SPIN TOP ENCLOSURES

For hazardous locations, you now can order Square D Spin Top enclosed starters completely wired and mounted on racks built to your specifications. Or we'll help you or your engineers design the racks. Either way, you get these advantages:

- Complete factory wiring and assembly
- Extremely simple installation
- Choice of 4 sizes of Spin Top enclosures for circuit breakers and starters

Write for details. Square D Company, 4041 North Richards Street, Milwaukee 12, Wis.

SQUARE D COMPANY

HOW TO SOLVE *heat transfer problems*

Here is the book to give you a quick view of heat transfer fundamentals and the calculations of applying them in the design of such equipment as feed-water heaters, condensers, boilers, internal-combustion engine cylinders, and fan coils. Emphasizes basic aspects and immediately useful calculations!

Just Published—3rd Edition

Introduction to HEAT TRANSFER

By Aubrey I. Brown and Salvatore M. Marco, both of The Ohio State University

Third Edition, 328 pages, 6x9, 70 illus., $6.75

Engineers encountering a growing number of problems in this field will appreciate the directness of the treatment. Third edition includes new chapters on fluid flow in the convection process and graphical and numerical methods applied to heat conduction problems.

Chapter Headings

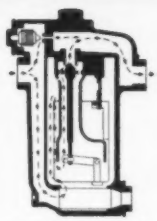
1. Modes of Heat Transfer
2. Heat Transfer by Conduction
3. Equations for the Calculation Conduction of Heat Transfer
4. Radiation
5. Fundamental Units and Dimensional Analysis
6. Fluid Flow in the Convection Process
7. Forced Convection
8. Free or Natural Convection
9. Heat Transfer to Boiling Liquids
10. Condensing Vapors
11. Over-all Transfer of Heat
12. Applications of the Principles of Heat Transfer to Design Problems
13. Transient Conduction
14. Graphical and Numerical Methods for Heat-conduction Problems

The Gulf Publishing Company

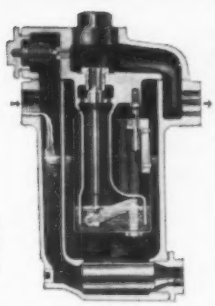
P. O. Box 2608

Houston 1, Texas

Now—A Steam Trap that Adjusts Automatically to Every Operating Condition!



Warm-up speeded by discharge through by-pass as well as main orifice.



In-line installation. All parts serviced without removing body from line.

AUTOMATICALLY REGULATES FOR FASTER WARM-UP AND TO KEEP OPERATING TEMPERATURE AT PEAK HEAT

Proven bucket design with built-in accessories. By-pass thermostat increases discharge for warm-up and overload conditions. Thermostat compensated to operate at 10° below saturated steam temp. Wright-Austin Airxpel principle provides for mechanical discharge of air after Thermostatic by-pass has closed.

WRITE FOR BULLETIN 808

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Chlorides of Aluminum, Antimony, Boron, Columbium, Silicon, Tantalum, Titanium and Zirconium in commercial quantities; chlorides of Chromium, Germanium, Tin and Vanadium in research or developmental quantities.

METALLO-ORGANICS

More than 300 organic, inorganic and metallo-organic chemicals are available from Stauffer's Anderson Chemical Division (Weston, Mich.); some in commercial, others in research or developmental quantities.

CATALYST SUPERMARKET

You will find a catalyst for almost any purpose among Stauffer's broad range of chemical products. They cover the chemical front from Al to Zr...are available in quantities for research or production...from ampules to tank cars... from 17 sources of supply coast to coast. Note the many types available:

MINERAL ACIDS

Hydrofluoric, Muriatic, Nitric and Sulfuric Acids available in drums to tank cars.

BROCHURES AVAILABLE

Metal Chlorides (36 pages)
Metallo-Organics (40 pages)
Hydrofluoric Acid (40 pages)
Muriatic Acid (44 pages)

Aluminum Alkyls are now available in developmental quantities and will be available in commercial quantities late this year.

Stauffer CHEMICALS SINCE 1885

STAUFFER CHEMICAL COMPANY

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P. O. Box 9716, Houston 15, Texas

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Men . . .

studied and developed catalysts for making synthetic petroleum products and for refining, and has specialized in improving oils and studying how they lubricate. He is a graduate of Karlsruhe Institute of Technology. He obtained his M.S. degree at the University of Munich and his Ph.D. degree in chemistry at Stuttgart Institute of Technology. He is a member of ACS.

G. W. Mayben has been named operating superintendent of American Oil Co.'s Baltimore refinery. He succeeds **William F. Mellendick** who is retiring after more than 42 years of service with Amoco.

Herman G. Gunter has joined Commonwealth Oil Refining Co., Inc. as assistant refinery manager. He has had broad experience in the oil refining industry, having been associated with Standard Oil Co. (N.J.) affiliates for 22 years. He more recently was with Suntide Refining Co. and Commerce Oil Refining Corp.

H. D. Armstrong has been elected treasurer of the Standard Oil Co. of Calif., succeeding **H. C. Judd,** who retired. Armstrong, who has been assistant to the chairman and is a director of various affiliated companies, joined Standard as assistant treasurer in 1943 after a career in law and banking. He is a graduate of the University of California and Hastings College of Law.

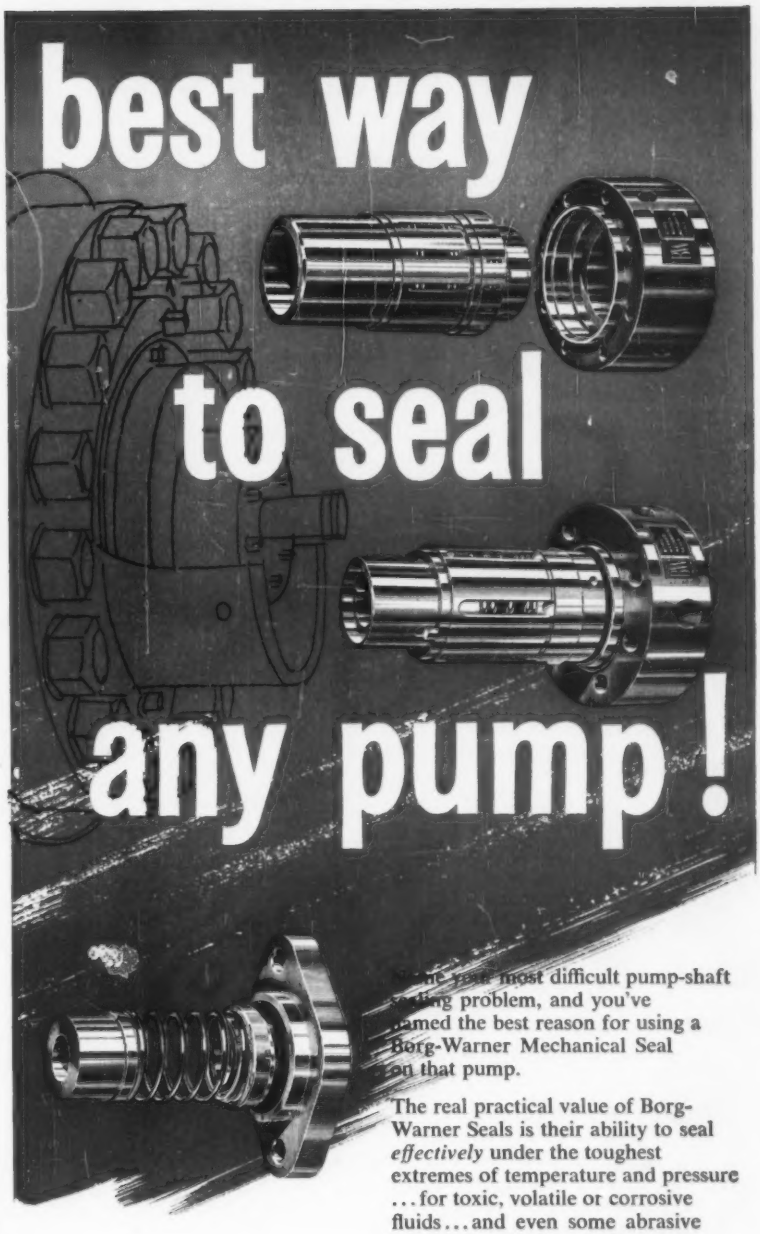
Lee C. Vogel has been promoted to senior research chemist at the Union Oil Co. of Calif. Research center, Brea, Calif. **J. G. Claypool** has been promoted to senior design engineer at the Research Center.

– Deaths –

Arthur S. Randak, 46, assistant Eastern division manager of Sinclair Refining Co. died May 5 in Boston. After a funeral service in Old Greenwich, Conn., he was buried in Arlington National Cemetery, Arlington, Va. Randak joined Sinclair in 1937 as a specialist in automotive and aviation fuels and lubricants. During his career with Sinclair he was chief automotive engineer, manager of the Technical Service division and, until his most recent assignment, manager of lubricating sales. He was also a director of Sinclair Research Laboratories, Inc., and chairman of Sinclair Refining Co.'s motor fuels steering committee.

Randak

W. D. Cross, Jr., 62, central regional vice president of Sinclair Refining Co., died May 12 in Elmhurst, Ill., after a brief illness. He lived at Glen Ellyn, Ill.



...most difficult pump-shaft ...ing problem, and you've ...amed the best reason for using a Borg-Warner Mechanical Seal ...on that pump.

The real practical value of Borg-Warner Seals is their ability to seal *effectively* under the toughest extremes of temperature and pressure ...for toxic, volatile or corrosive fluids...and even some abrasive liquids. *Result*—less down time, elimination of expensive stuffingbox maintenance, and savings of the pumped fluid.

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NOW AVAILABLE—a new file folder of Borg-Warner Mechanical Seal designs shows some of the many types and applications possible for pumps, mixers, autoclaves and for special rotating shaft problems. Send for your copy today—there's no obligation!

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Suppliers Notes...

Williams

R. D. Williams has been named sales manager, California district, The Philip Carey Manufacturing Co., Cincinnati. The California district serves California, Arizona and New Mexico. Williams will be in charge of the Los Angeles and San Francisco warehouse operations, all district sales representatives and the San Francisco Contract division. He will headquarter at Carey's San Francisco office. Williams has been with Carey 25 years, in various sales jobs.

Howard D. Hartough has been elected president of the Chemical Products division, Chemetron Corp., with headquarters in Louisville. He has been general manager of Girdler Catalysts, Louisville. Hartough was previously manager of marketing, Chemical Products division, Houdry Process Corp., and before that was with Socony-Mobil Research laboratories and Hercules Powder Co. He holds chemistry degrees from Hope College and George Washington University.

Hartough

Bielek

Ivan R. Bielek has been named manager of newly established chemical-cleaning service and operating facilities at Ventura, Calif., for Dowell division, The Dow Chemical Co. He has been with Dowell since 1947, serving in all capacities of the company's chemical-cleaning services. A former treating engineer, sales engineer, and field development engineer throughout the Mid-East, he has a petroleum engineering degree from the University of Pittsburgh.

Nathaniel Brenner has been named manager of applications engineering, Instrument division, Perkin-Elmer Corp. He joined P-E in 1956 as an applications engineer, Instrument division, and became laboratory supervisor the same year. In 1957, he became product specialist, Instrument division, the job held before his recent appointment. Before joining Perkin-Elmer, Brenner was a spectroscopist with Aero Materials Laboratory, U.S. Navy, Philadelphia.

Brenner

Anderson

James S. Anderson, vice president in charge of sales for The Babcock & Wilcox Co.'s Tubular Products division, has been appointed general manager of the division. Anderson joined B & W in 1941 in the division's New York office. He became assistant manager there in 1942 and assistant general sales manager in 1948. He became sales manager in 1953, and vice president in 1957. Anderson has a mechanical engineering degree.

Carl J. Maki has been named assistant to the executive vice president, Dresser Industries, Inc. Maki joined Dresser from Texaco, Inc., where he was assistant to the manager, Gas division. Previously, he was with the Seaboard Oil Co. as Gas Department manager until that company merged with Texaco in 1958. Before that, Maki had been with Gulf Oil Corp., Mene Grande Co., and Phillips Petroleum Co.

Maki

Kruse

W. Nicholas Kruse has joined the home office engineering sales staff of Badger Manufacturing Co., Cambridge, Mass. He received his B.S. degree in chemical engineering, and, after three years with Army Ordnance, joined Universal Oil Products Co., where he was in pilot plant research, field operations and product sales. In 1951, he moved to Procon, Inc., where he went into project engineering and petroleum refining sales.

Ernest G. Hotze has been named Southwest district manager for Clark Bros. Co. He will be responsible for the sale of engines, compressors and gas turbines throughout Texas (except the Panhandle area), Mississippi, Louisiana, Southern Arkansas and Southern New Mexico. Hotze has been with Clark since 1942, serving as technical service engineer, sales engineer, assistant district sales manager, and since 1955, Houston District Manager.

Hotze

Stabile

Edmund W. Stabile has joined B-I-F Industries, Inc., Providence, R. I., as a petro applications engineer. He attended the Y.M.C.A. Institute of Providence in 1954, and graduated from the University of Rhode Island in 1958 with a B.S. degree in electrical engineering. He was previously employed by New England Telephone & Telegraph Co., Boston, as a radio and television engineer. From 1950-54 he was in the Air Force.

Hugh C. Newton of Rockwell Manufacturing Co.'s Public Relations department has been named assistant director of public relations. He joined Rockwell in January, 1959. Previously, he was Rockwell's public relations representative as an account executive for Burson-Marsteller Associates. Before that, he was a reporter for the Danville, Va., *Bee;* editor of Carnegie Institute of Technology's news service, and a staff assistant

Newton

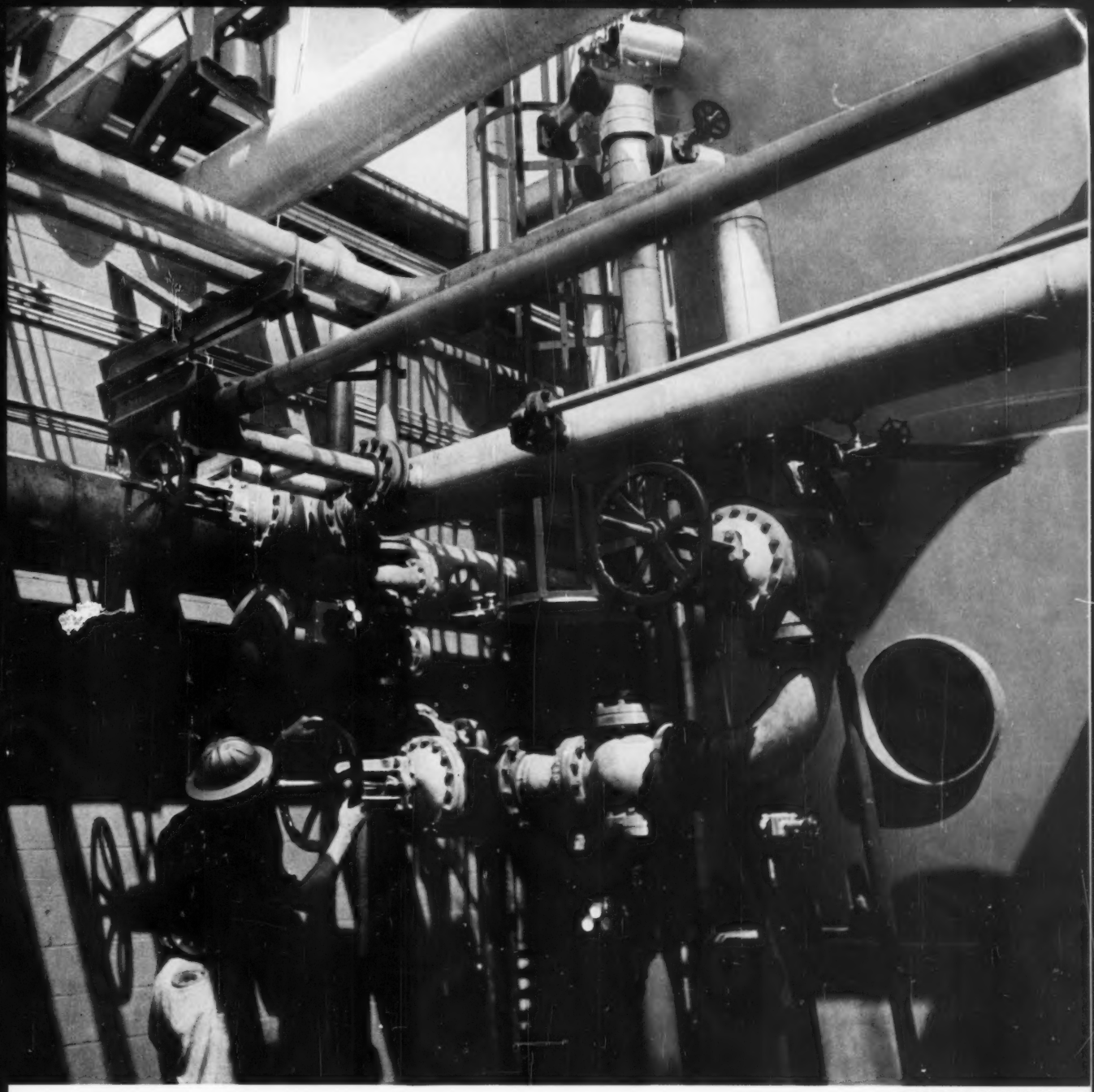

PHOTO ON ANSCOCHROME

SPECIAL PROCESS...General Aniline & Film Corporation's new plant at Linden, N. J., went on stream last year. Built by Scientific Design Co., Inc., it produces ethylene oxide by direct air oxidation of ethylene, Scientific Design's own efficient and economical process. The Aloyco Stainless Steel Valves here (red hand wheels) were selected for their design features and long life expectancy. On your next stainless steel valve job, why don't you talk first to the one company which specializes in high alloy valves exclusively. For further details about Aloyco Valves, write us at 1301 West Elizabeth Avenue, Linden, New Jersey. 9.5

ALLOY STEEL PRODUCTS COMPANY

Boston · New York · Wilmington · Atlanta · Buffalo · Pittsburgh · Chicago · St. Louis · San Francisco · Los Angeles

"The tendency for governments to exert more and more control over business affairs affects the ability of all private investment to serve people and earn a proper return. Often such actions have results beyond those intended, to the detriment of investors, consumers, and free world prosperity and security."

—From the 1958 Annual Report

Standard Oil Company (New Jersey)
and affiliated companies

ESSO

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Suppliers . . .

for Westinghouse Electric Co. Newton graduated from Washington and Lee University, and is a member of the Pittsburgh Press Club and Sigma Delta Chi, national professional journalism fraternity.

Chehak

Luber

LINK BELT SPEEDER CORP. has elected **C. M. Basile, N. V. Chehak** and **M. P. Luber** to management positions. Basile joined the organization in 1950 as vice president in charge of manufacturing. Since 1955, he has been vice president of manufacturing and sales. A new vice president and sales manager, Chehak, had served since 1958 as sales manager. A graduate of the University of Wyoming, he was with three different construction firms before joining Link-Belt in 1948. Luber was elected vice president of manufacturing. A graduate engineer from Iowa State College, he started with the company as plant layout engineer in 1946.

Basile

HILLS-McCANNA CO. has appointed **Geo. S. Thomson Company, Inc.,** El Paso, a stocking distributor for its diaphragm valves and replacement parts. The firm will serve West Texas and New Mexico.

CRANE CO has named **George F. Burley** vice president for sales. Other appointees were **Clarence E. Watson,** general manager of atomic energy sales; **Darrell R. Nordwall,** general manager of branch sales; **Charles H. Lovelace,** general manager of engineering sales, and **R. W. Lindsay,** general manager of wholesaler sales. The four will headquarter at the Chicago general offices.

THE OKONITE CO. has named **Thomas M. Brickley, Jr.,** district manager, Milwaukee district office. A graduate of the University of Wisconsin, he was formerly with Brickley and Co., manufacturers' agent, Milwaukee.

INTERNATIONAL NICKEL CO. OF CANADA, LTD., has named **Thomas Archibald Stone** special assistant to the president. He will also serve as special assistant to the president of The International Nickel Co., Inc., with headquarters in New York. Canadian ambassador to the Netherlands

W-S

Drop Forged from Solid Billets...

FORGED STEEL FITTINGS

Heat . . . pressure . . . turbulence . . . oxidation . . . vibration . . . reduction . . . shock. For critical installation problems like these, get maximum protection with W-S Carbon, Stainless and Alloy Steel Fittings.

- Drop forged to produce exceptionally high tensile and impact strength.
- Long accurate threads, in perfect alignment, for ease of installation.
- Heavy uniform fitting wall thickness—an important safety factor.
- Accurate machining to fit tight.

For your next order, call your nearby W-S Distributor. You'll find him ready with comprehensive stocks of the complete line of W-S high-quality fittings. *Forge & Fittings Division, H. K. Porter Company, Inc., Box 95, Roselle, New Jersey.*

FORGE AND PORTER FITTINGS DIVISION

H.K. PORTER COMPANY, INC.

Divisions: Connors Steel, Delta-Star Electric, Disston, Forge & Fittings, Leschen Wire Rope, Mouldings, National Electric, Refractories, Riverside-Alloy Metal, Thermoid, Vulcan-Kidd Steel, H. K. Porter Company (Canada) Ltd.

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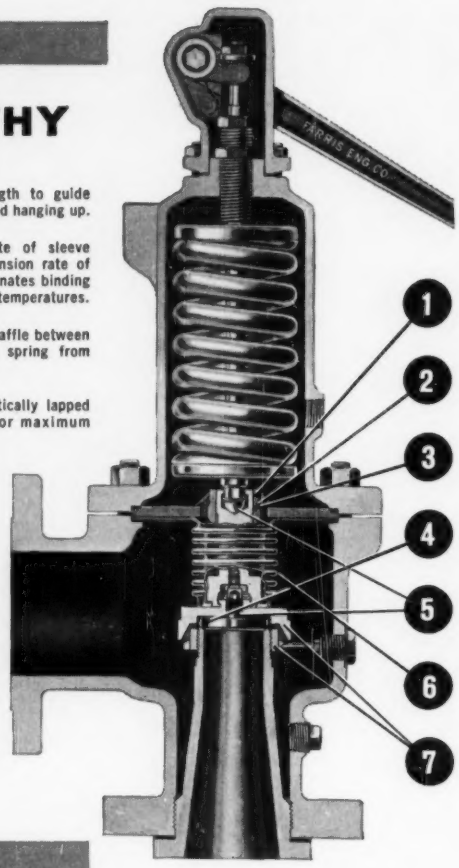
OUTSELLS THEM ALL!

HERE'S WHY

1. 2½ to 1 ratio – guide length to guide diameter–prevents galling and hanging up.
2. High thermal expansion rate of sleeve guide and low thermal expansion rate of hardened stem retainer eliminates binding and galling even at elevated temperatures.
3. Sleeve guide provides solid baffle between body and bonnet, shielding spring from lading fluid.
4. Hardened stainless steel optically lapped flat disc – self aligning for maximum tightness.
5. Double universal ball joint from stem to disc for self alignment – eliminates effects of spring, temperature and piping distortion.
6. Stainless steel "BALANSEAL" bellows nullifies effect of back pressure and isolates internal working parts from lading fluid.
7. Cone-shaped disc holder directs flow away from guiding surfaces and forms fixed secondary orifice with single blowdown ring control for built-in capacity.



Farris full nozzle Safety-Relief Valves

Simplicity in design, safety in operation ... what more can you ask of a Safety-Relief Valve! The patented design features shown in this Farris valve have been *standard* for more than a decade. It's the ideal concept of a trouble-free, safe, safety valve, free from inventory and design change problems since 1945. It's the *preferred design* in full nozzle safety-relief valves for the process industry.

Detailed information for the selection and sizing of all Farris process safety-relief valves is in Catalog FE-118. Sent to you on request.

PROGRESS THROUGH Farris HONEST PURPOSE

ENGINEERING CORP.

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Texas Plant: 5405 Clinton Drive, Houston 20

affiliates: FARRIS FLEXIBLE VALVE CORP. • FARRIS PICKERING GOVERNOR CO., INC. • FARRIS ENGINEERING LTD., LONDON, ENGLAND

Suppliers . . .

from 1952-58, he has resigned from the Department of External Affairs at Ottawa. Since entering External Affairs in 1926, and prior to becoming Ambassador to the Netherlands, he had been Canadian Minister in Washington, Envoy Extraordinary and Minister Plenipotentiary to Sweden, and served in other key posts in Ottawa, London and Paris.

ROCKWELL MANUFACTURING CO.'s Meter and Valve division has named **Gilbert T. Bowman** vice president. He will be in charge of the International and Petroleum and Industrial divisions. Bowman joined Rockwell in 1940 as a meter and valve sales engineer in Northern California, became San Francisco district sales manager in 1945, sales manager-Gas Products and Nordstrom Valves in 1952 and general products manager in 1954. He was promoted to his most recent position in 1956.

Bowman

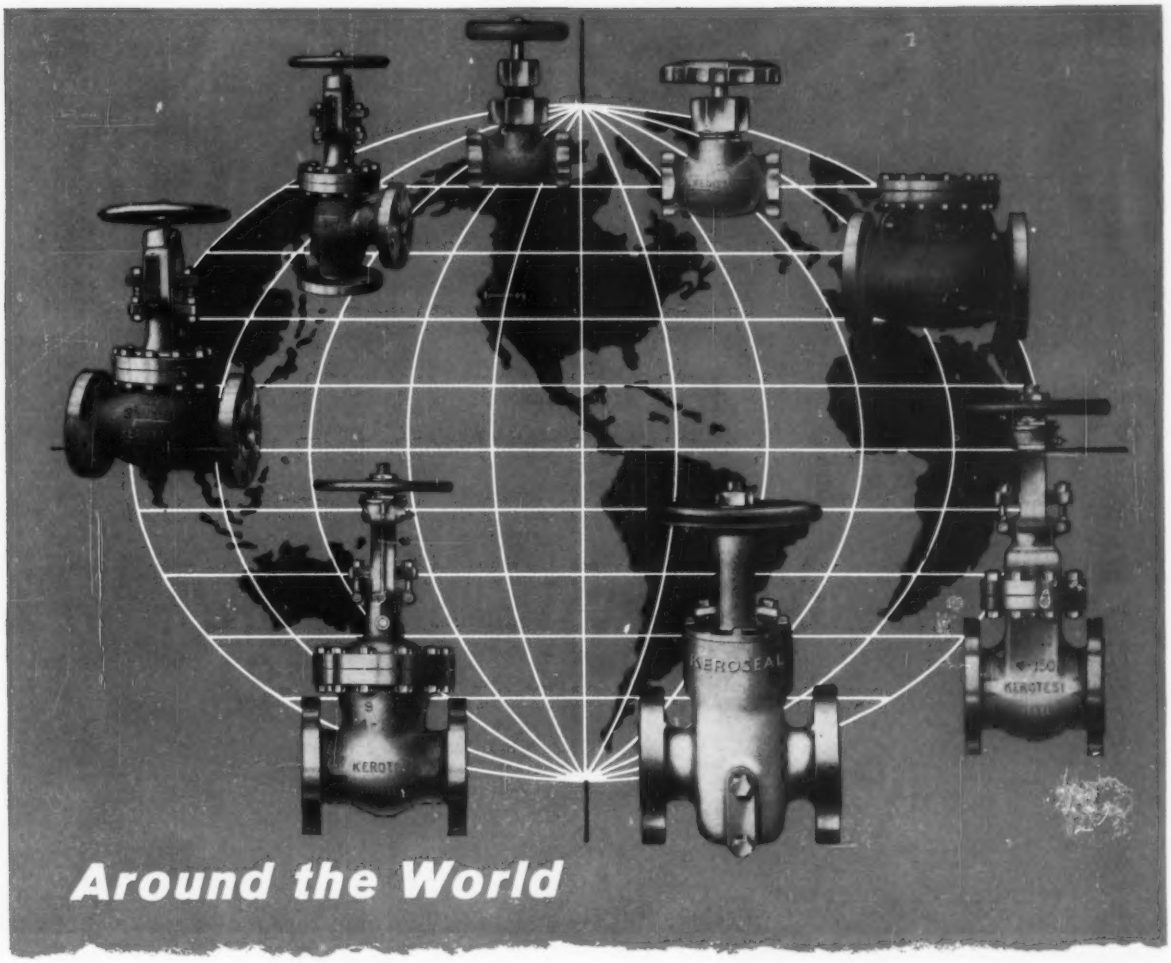
WOLVERINE TUBE has named **John W. Baker** technical sales representative, Philadelphia. A chemical engineering graduate formerly with Harshaw Chemical Co., he will work with the processing, refining and power fields along the East coast from Eastern Pennsylvania to Southern Florida.

CLAYTON MARK & CO. has named **Roy W. Gronauer** sales manager of industrial fittings. He will direct the company's sales representatives and engineers. Gronauer was formerly sales vice president of OPW Corp., but resigned in 1957 to become a manufacturers' representative in Cincinnati.

CALUMET & HECLA, INC.'s Wolverine Tube division has named **L. A. Brewer** sales representative, Rochester, N. Y. Formerly assistant purchasing agent for Trane Co., La Crosse, Wis., he will now sell and promote Wolverine's industrial and processing products. He will operate in Western New York State.

THE SWARTWOUT CO. has appointed **S. W. Thompson** sales engineer. He will open a New Orleans office for the firm at 1119 Richards Building. Before joining Swartwout Thompson was New Orleans branch manager for Moore Products Co. He is a graduate of Drexel Institute of Technology.

JONES & LAUGHLIN SUPPLY DIVISION has given new assignments to **R. J. Bevington,** salesman at Freer, Texas, transferred to McAllen, Texas; **R. D. Landis,** salesman, transferred from Alice, Texas to Freer; **C. L. Wallace,** salesman at Houma, La., transferred to Brookhaven, Miss.; **B. W. Ramsey,** salesman at Lake Charles store, transferred to Houma; **H. E. Reeves,** salesman at Brookhaven, transferred to Natchez, Miss., and **D. R. Mc-**



...and 50 Years of quality VALVES

Visit oil and gas industries, processing and other industrial plants in any country in the world and you will find Kerotest Valves at work in a multitude of jobs. This universal acceptance of Kerotest Valves is the result of a continuous effort toward product improvement ever since the company was founded in 1909.

Around the world and 50 years later, Kerotest still continues to make highest quality valves, with consistent effort toward even greater product improvement. Each step in Kerotest Valve manufacture, from raw materials to final rigid inspection, is the result of research and engineering directed solely to obtaining better product performance on the job. The results of these efforts have set Kerotest Valves apart from the ordinary and have maintained their high standards of quality everywhere.

For additional information on valves for your requirements, write today for the latest Kerotest brochure.

KEROTEST QUALITY VALVES FOR EVERY REQUIREMENT

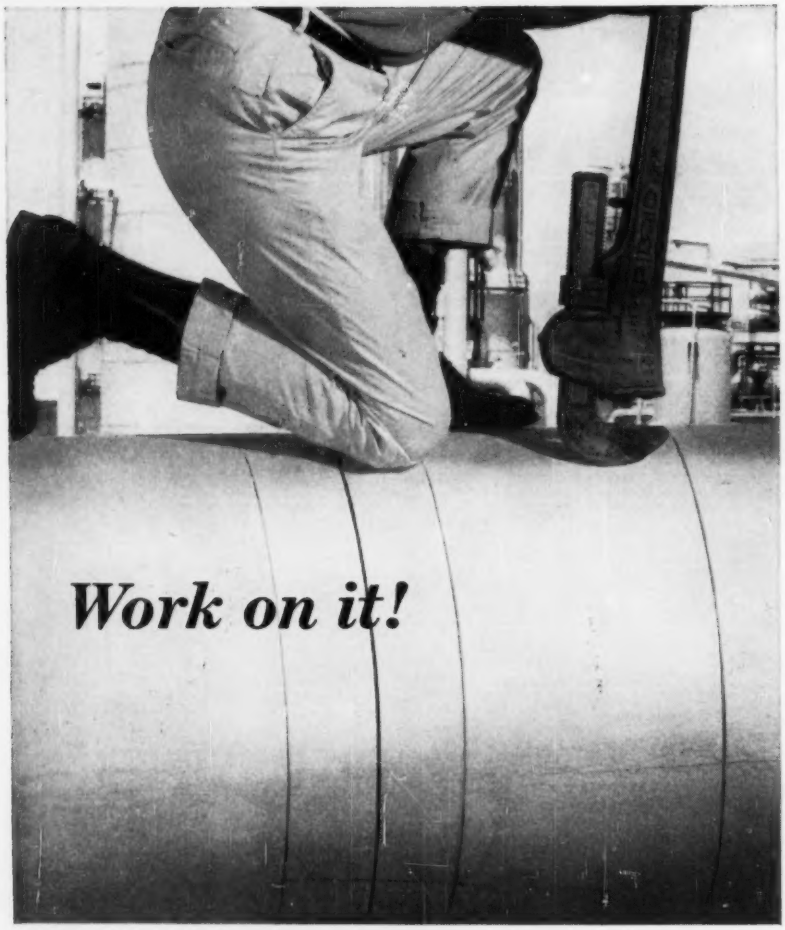
- Gate Valves
- Globe Valves
- Angle Valves
- Check Valves
- Pipe Line Valves
- Positive Shut-Off Valves
- Production Valves
- Needle Valves
- Well Head Equipment
- General Purpose Valves
- Special Valves

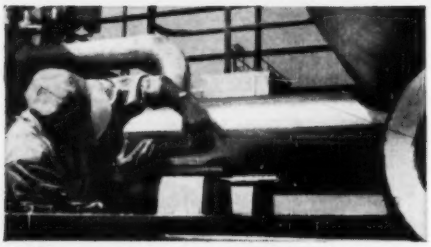
KEROTEST MANUFACTURING COMPANY

2514 LIBERTY AVENUE • PITTSBURGH 22, PA.

In Canada, Kerotest products are manufactured and distributed exclusively by Guelph Engineering Company, Guelph, Ontario.

KEROTEST





J-M's new Metal-On® insulation is Thermobestos prejacketed in aluminum. Snaps on pipe quickly . . . surely. Saves the time and cost of separate on-the-job metal application.

Seminars on best installation practices. For plant foremen who wish to keep up to date on new insulation methods and installation practices, J-M regional sales offices will gladly conduct insulation seminars. Contact nearest J-M office.

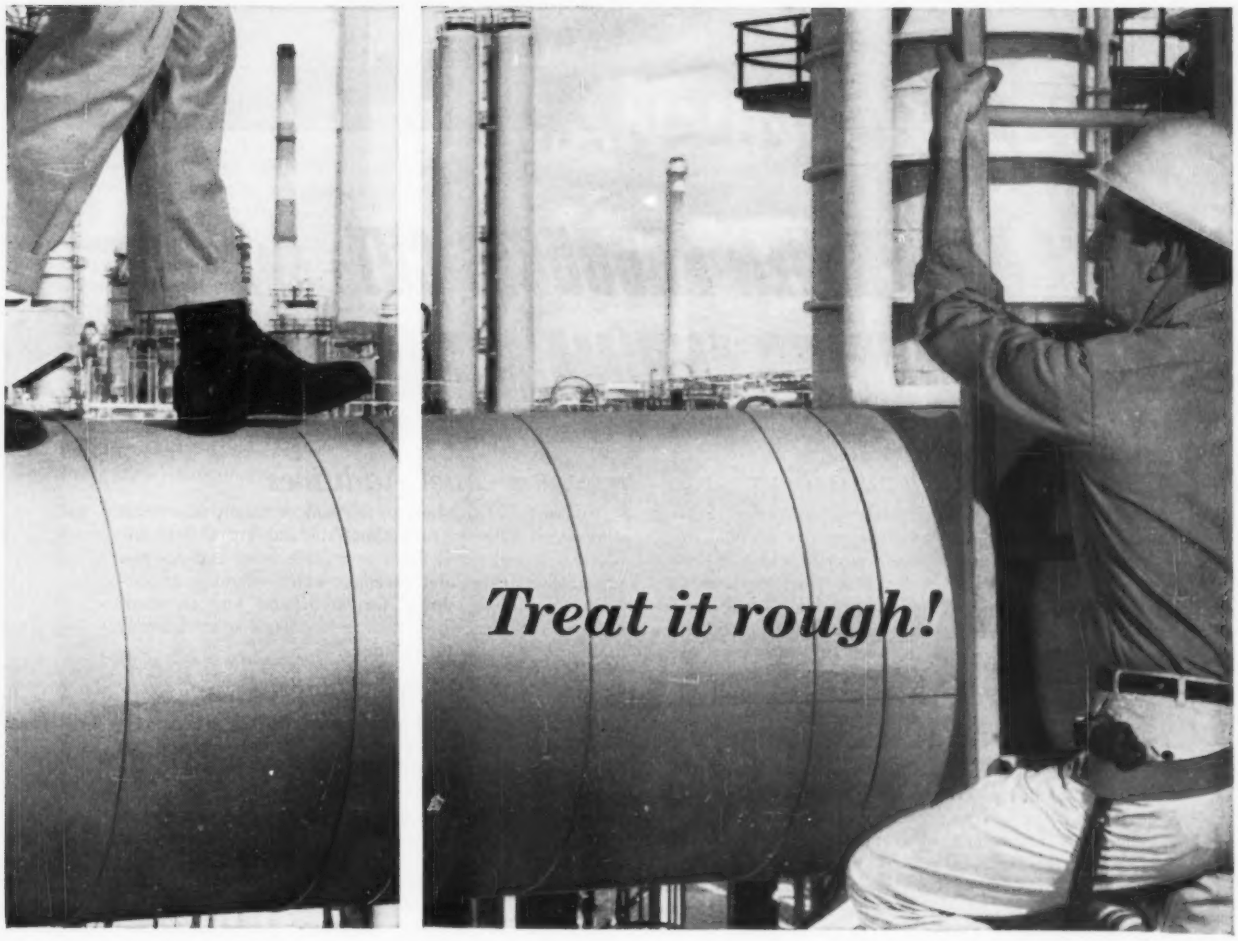
It's tough, durable Johns-Manville

Here's why Thermobestos is the preferred high-temperature calcium-silicate insulation . . . to 1200 F

You know the kind of treatment pipe insulation must take . . . day after day, year after year!

There's no better reason than this for the spiraling growth in Thermobestos® applications throughout the process and power generation industries —an insulation so strong and rigid, so resistant to crushing and compression it is almost structural.

For more data on advertised products, use Readers' Service Cards, last page.

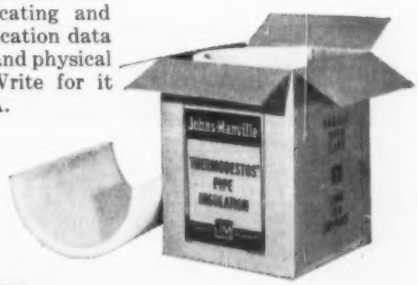


THERMOBESTOS insulation!

Equally important is the ability of Thermobestos to keep fuel costs low. Its *k* factor is the lowest of all insulations generally accepted for process applications. Its moisture resistance, unsurpassed.

Furnished in large, lightweight sections—precision-molded to unusually close tolerances—Thermobestos is easy to handle and install . . . readily adaptable to shop fabrication of fittings and bonds. Large selection of sizes, thicknesses (and quads up to 33″ pipe size) permit calcium-silicate installations that are entirely Thermobestos insulation.

You'll want the new Thermobestos booklet for your technical file. It contains complete information on prefabricating and installation practices . . . specification data . . . heat transmission tables . . . and physical and thermal characteristics. Write for it today. Ask for booklet IN-169A. Address Johns-Manville, Box 14, New York 16, N.Y. In Canada, 565 Lakeshore Rd. East, Port Credit, Ontario.



JOHNS-MANVILLE PRODUCTS

JOHNS-MANVILLE

another
TRETOLITE SERVICE
report

THESE USE-PROVEN PRODUCTS CUT MANUFACTURING AND MAINTENANCE COSTS

TRET-O-LITE* *Demulsifiers*

TRET-O-LITE Demulsifying Chemicals separate an aqueous phase from a hydrocarbon phase, or vice versa.

Separation procedure consists simply in mixing a small proportion of the selected TRET-O-LITE with the emulsion and providing suitable storage where the oil and water can separate.

TRET-O-LITE Demulsifiers are used to treat tank "bottoms," also Bunker "C" fuels for the removal of salts and trace metals to permit the use of such fuels in gas turbines.

TRET-O-LITE* *Chemical Desalting*

TRET-O-LITE Chemical Desalting removes harmful salts from crude oil in the 95% to 100% efficiency range, and is currently being used to process over 1½ million barrels of crude daily. Chemical costs average 1.3 mills per barrel.

Experienced Tretolite refinery service engineers inspect construction, supervise start-up and make periodic inspections of the Tretolite desalting equipment. It can be purchased, rented, rented with option to purchase, or constructed by the refiner according to plans furnished by Tretolite.

KONTOL* *Corrosion Inhibitor*

KONTOL Corrosion Inhibitor is a liquid organic semi-polar compound, available in various formulas. It adsorbs onto metal surfaces to form impervious corrosion-inhibiting film. KONTOL Corrosion Inhibitors prevent corrosion in hydrocarbon distillation systems by protecting against attack by chlorides, sulfides, organic acids, other corrosive agents and hydrogen blistering. They also have effective detergent properties at temperatures above those considered normal for this type of inhibitor.

TOLAD† *Fuel Additives*

TOLAD Fuel Oil Additives are ashless, totally oil-soluble compounds designed to enhance the stability of domestic heating oil and diesel fuels, as regards color and residue. These additives exhibit excellent water tolerance characteristics reducing sludge formation and loss to water bottoms in fuel storages. They are available as inhibitor or inhibitor-dispersant formulations.

KUPLEX* *Metal Deactivator*

KUPLEX Metal Deactivator prevents the pro-oxidant effects of copper and its compounds from causing the degradation of petroleum distillates. It prevents degradation reactions by tying-up the dissolved metal as an inactive stable chelate. At concentrations as low as 8 ppm it can reduce anti-oxidant requirement and assure fuel stability. It is effective in gasoline, kerosine, jet fuel, diesel fuel, furnace oil and turbine oil.

TRET-O-LITE* *Water De-Oilers*

The disposal of refinery wastes often results in the loss of valuable refined products, may also lead to the creation of a stream pollution nuisance. Many refiners use TRET-O-LITE Water De-Oilers to correct such problems. The efficient demulsification of waste oil emulsions often makes possible the salvage of large quantities of oil, as well as the lessening of the pollution problem. Tretolite chemicals are in daily use for reclaiming oil from slop disposal systems and separator traps.

For complete information on these, or any Tretolite Company product or service, *ask the Man in the Red Car,* or write

AR-59-1

*TRET-O-LITE, KONTOL *and* KUPLEX *are registered trademarks of Petrolite Corporation*

†TOLAD *is a Petrolite Corporation trademark, registration pending*

PETROLITE CORPORATION

TRETOLITE COMPANY
DIVISIONS
369 Marshall Avenue, Saint Louis 19, Missouri
5515 Telegraph Road, Los Angeles 22, California

CANADA: Petrolite Corporation of Canada, Limited, 309 Alexandra Bldg., Edmonton, Alberta

ENGLAND: Petrolite Limited, 46 Mount Street, London, W. 1.

VENEZUELA: South American Petrolite Corporation, Hotel Avila, Caracas

REPRESENTATIVES

BRAZIL: WERCO, Ltda., Avenida Rio Branco 57-s/1410-11, Rio de Janeiro
COLOMBIA: South American Petrolite Corporation, Calle 19, No. 7-30, Office 807, Bogota
GERMANY: H. Costenoble, Guiollettstrasse 47, Frankfort, a.M.
ITALY: NYMCO S.p.A. 9, Lungotevere A. da Brescia, Rome
JAPAN: Maruwa Bussan KK, No. 3, 2-Chome, Kyobashi, Chuo-Ku, Tokyo
KUWAIT: F. N. Dahdah, Box 1713, Al Kuwait
MEXICO: R. E. Power, Sierra de Mijes, No. 125, Mexico, D. F.
NETHERLANDS: F. E. C. Jenkins, Hoefbladlaan 134, The Hague
PERU: International Gas Lift Company, Apartado 71, Talara
TRINIDAD: Neal and Massy, Ltd., Port of Spain, P.O. Box 544

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

Kown, salesman at Williston, N. D., transferred to the Houston sales office.

Promoted to salesmen at their present location, are **P. A. Toomey,** storeman at Williston, and **T. D. Gholson,** a graduate of J&L's sales training program, assigned to the Houston sales office.

WORTHINGTON CORP.'s Charles D. Wood, Boston district office, has been appointed district office manager. He is a graduate of the University of Tennessee with a degree in mechanical engineering. He joined Worthington at Boston in 1939 as an application engineer. Following wartime military service, he returned to Boston as application and field service engineer and technical representative. Wood is a member of the Massachusetts Society of Professional Engineers.

THE BABCOCK & WILCOX CORP.'s Boiler division has named **John G. Martin** domestic sales manager. He will headquarter in Barberton, Ohio, site of the division's largest manufacturing plant. Succeeding Martin as manager, Cincinnati district sales office, is **William E. Butler,** former sales engineer, Syracuse office, New York sales district.

Martin

Martin received a degree in mechanical engineering in 1929—then joined B & W as a student engineer in Barberton.

W-K-M DIVISION OF ACF INDUSTRIES, INC. has named **Henry C. Tooley** plant manager for its Missouri City, Texas, plant. He will be responsible for all manufacturing functions. Tooley was formerly with Reed Roller Bit Corp., his last position being executive vice president before joining Cameron Iron Works for a special assignment.

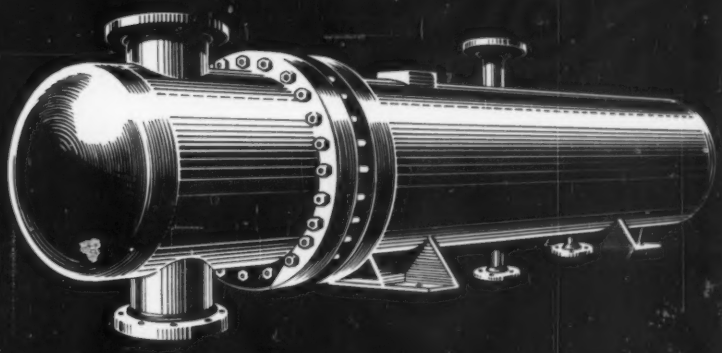
WALWORTH CO. has named **Richard F. Arnold** district manager, Oklahoma sales, Tulsa. He has been with Walworth six years as a salesman in the Dallas, Fort Worth and Wichita Falls area. Before that, he was employed by Remington Rand Co.

CRANE CO. has elected **Thomas Evans** chairman and chief executive officer. New directors in addition to Evans, were **Alfons Landa, Robert B. Crane** and **E. A. Locke, Jr.**

THE OKONITE CO. has named **James R. Haden** district manager, Kansas City district office. He has operated this office, formerly a branch of the St. Louis district, since 1954. A graduate of the University of Missouri, Haden has been with Okonite since 1950.

BECKMAN INSTRUMENTS, INC.'s Scientific and Process Instruments division has named **Richard C. Erbes** and **Frank Kelley** product line managers, Fullerton, Calif. Erbes will direct sales and product

MANNING & LEWIS



M & L CARBON STEEL REACTIVATION CHILLER made to A.S.M.E. code. (Dimensions 18" outside diameter shell, 7' overall length, weight 2000 pounds).

Today's rapid strides in the technology of processing plant operation make it essential for a manufacturer of equipment to be "staffed up" with people who have had extensive training and experience. More than half our staff have spent a major part of their working life in this one field and have played a major role in the design and fabrication of many types of processing equipment. They know the limitations and workability of all metals and how to get maximum service from each. This accumulated knowledge of base materials and our extensive experience in design and fabrication means practical, trouble-free equipment at the lowest possible cost.

It is impossible, in a field requiring such wide diversification, to illustrate, or even list, all the products we have been called upon to supply. The chiller above is simply one among thousands.

Call on us the next time you need equipment. We are fully qualified to design and fabricate to all codes.

M&L MANNING & LEWIS

ENGINEERING COMPANY

Dept. C, 28-42 Ogden Street, Newark, New Jersey

DESIGNERS & MANUFACTURERS OF QUALITY HEAT EXCHANGE EQUIPMENT

For more data on advertised products, use Readers' Service Cards, last page.

Here's a steam trap

..and for seven sound reasons:

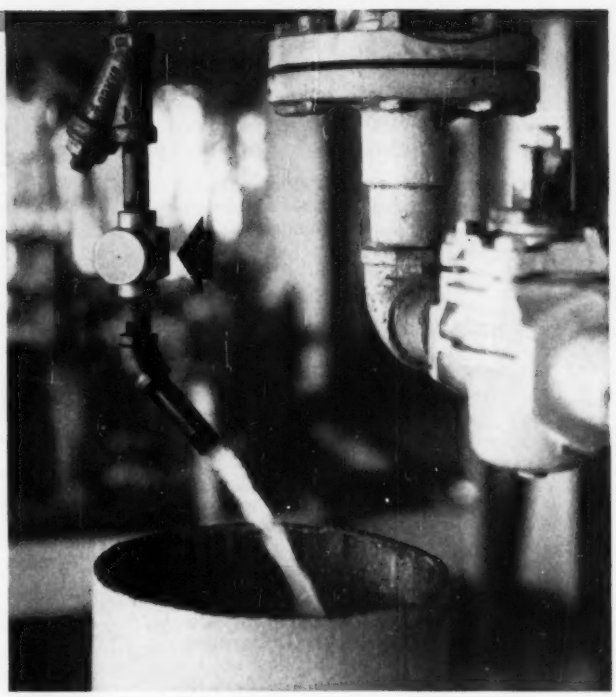
1. *Simplicity* – only one moving part.

2. *Maintenance* – practically zero. 3. *One trap* for all pressures from 10 to 600 psi.

4. *Uniform performance* – operates equally well on heavy, light, or no condensate load.

5. Operates against *back pressures* up to 50% of inlet pressure. 6. *Rugged* – unaffected by superheat, water hammer, vibration, or corrosive condensate. 7. *Minimizes inventory* of spare parts.

Sarco TD's on outdoor blending tanks of Shell Oil Company, Sewaren, New Jersey, are installed vertically, instead of in the usual horizontal position, in order to drain coils after shut-down, thus preventing freezing.



1. DRAINS AND VENTS

at start-up. Immediately rids lines of condensate and air to permit normal operation. This eliminates the need for manual opening of valves to drain the system.

CONTROL COSTS

In these days of sharp emphasis on cost control, Sarco Thermo-Dynamic TD Traps are helping plants to deliver the full productive power of every pound of steam. And because the TD has no mechanism . . . no gaskets . . . no narrow channels to clog, maintenance cost on the TD is almost nil. As one plant engineer puts it: "This TD is a cinch to install, it's no bigger than a tee fitting, and it works in any position. The TD is the one steam trap we can install and forget."

CHOOSE THE RIGHT TRAP

There's an infinite variety of applications, temperatures, pressures and loads in industrial steam piping. Sarco can help you select the right trap for every job of air and condensate removal, saving you money and down-time.

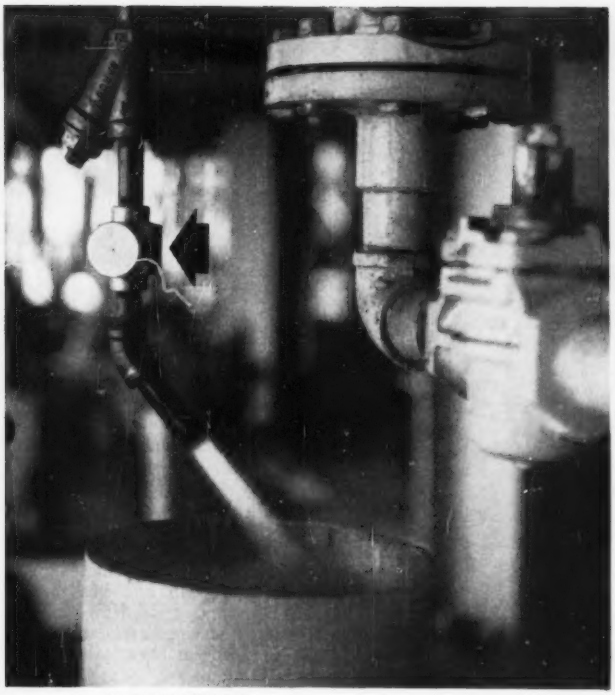
HOW ABOUT THE BUCKET TRAP?

With the development of the patented* Sarco Thermo-Dynamic Steam Trap, the bucket trap suddenly aged 50 years. In a nostalgic way we feel somewhat sorry, because *our* Sarco bucket trap has made us thousands of friends. But frankly, it's no match for the new Sarco TD. Progress is progress.

Some of our customers who are getting satisfactory service from our bucket traps may prefer to replace their old Sarco bucket traps with *new* Sarco bucket traps. If you feel this way, we're flattered enough to keep on making Sarco Bucket Traps – strong, sturdy and durable as ever. Let us suggest, however, that you at least give the new Sarco Thermo-Dynamic Steam Trap a try, under your most exacting conditions.

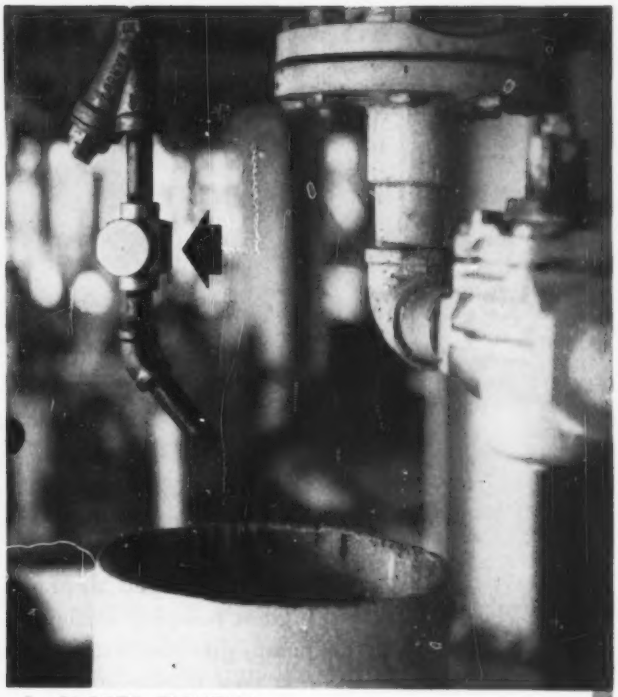
*U.S. Pat. No. 2,817,353 T. M. Reg. U. S. Pat. Off.

that does what a steam trap should



2. DISCHARGES

air and condensate at steam temperature as rapidly as they collect. Does not wait for a bucket of steam to leak through a small orifice.



3. CLOSES TIGHTLY

There is no continuous bleed; nor is there loss of buckets of steam as in the bucket trap which must discharge steam with each cycle.

Because Sarco makes all 5 types of steam traps — Thermo-Dynamic, Thermostatic, Liquid Expansion, Float Thermostatic and Camlift Bucket — you can get impartial advice on traps from these Sarco Companies:

SARCO COMPANY, INC.
635 Madison Avenue,
New York 22, N. Y., U.S.A.

Spirax-Sarco, Ltd.
Charlton House
Cheltenham, Glos., England (A)

S. A. Sarco
142, Rue Oberkampf
Paris XI, France (A)

SARCO CANADA LIMITED
611 Gerrard Street, E.,
Toronto 8, Ont.

Sarco G.m.b.H., Regel-Apparatebau
Reichenaustr. 212
Konstanz, Germany (A)

Sarco Belge, S.A.
Maisstraat 8, Ghent, Belgium (A)

Jucker S.p.A.
Milan, Italy (L)

Ing. Fliesberg, Akt.
Stockholm, Sweden (L)

J. Mas Nieto
Caspe 59, Barcelona, Spain (L)

SARCO INTERNATIONAL CORP. (A)
2 Park Ave.
New York 16, N. Y., U.S.A.

S. A. T. I. C.
Avda. Belgrano 1478,
Buenos Aires, Argentina (L)

Especialidades Industriales, S. A.
Monterrey and Mexico City,
Mexico (L)

(A) Affiliate (L) Licensee

6345

See Demonstration, Sarco Booth 596, World Petroleum Exposition, Coliseum

SARCO COMPANIES

STEAM TRAPS • TEMPERATURE CONTROLLERS • STRAINERS • HEATING SPECIALTIES

For more data on advertised products, use Readers' Service Cards, last page.

reputation for dependability

THERE'S A REASON why more and more Motorpumps are being specified today in all types of industry:

Only the Ingersoll-Rand Motorpump combines proven features with modern design engineering that provide rugged dependability, highest pumping efficiency. Motorpumps give you ease of installation, low cost operation and minimum maintenance.

To meet your particular requirements, Motorpumps are available in the widest range of sizes and types. Capacities go from 5 to 2800 gallons per minute; heads to 650 feet. Write today for the latest bulletin.

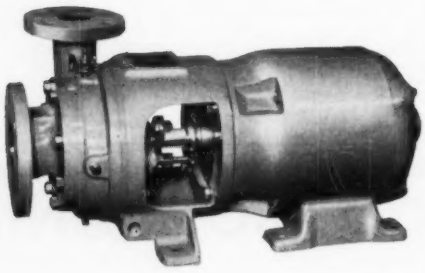
Ingersoll-Rand

9-828 ♥ 11 Broadway, New York 4, N. Y.

Ingersoll-Rand

MOTORPUMP

From ¼ hp to 75 hp



Suppliers . . .

planning of gas analysis and acidity-alkalinity measuring instrumentation. Kelley will be responsible for ultraviolet analytical instruments. Erbes was formerly assistant sales manager for laboratory instrumentation. Before joining Beckman he was with Arrowhead and Puritas Waters, Inc., Los Angeles. A graduate of U.C.L.A., he is a member of the Society for Applied Spectroscopy. Kelley was sales engineer for General Electric Co.'s instrument department, Lynn, Mass., before joining Beckman in 1957.

Wilson

Staudt

WILSON SUPPLY CO.'s Wallace D. Wilson has been elected president, and **John G. Staudt** vice president of the Petroleum Equipment Suppliers Association. Wilson is president of the Wilson Supply and Staudt is executive vice president and a director of Dowell Division of the Dow Chemical Co., with Tulsa headquarters.

AMERICAN CYANAMID CO.'s Industrial Chemicals division has appointed **R. C. Sarfaty** assistant manager of advertising. He joined Cyanamid in 1945 and has held a variety of sales and administrative posts, most recently serving as a sales representative for the process chemicals department in New England.

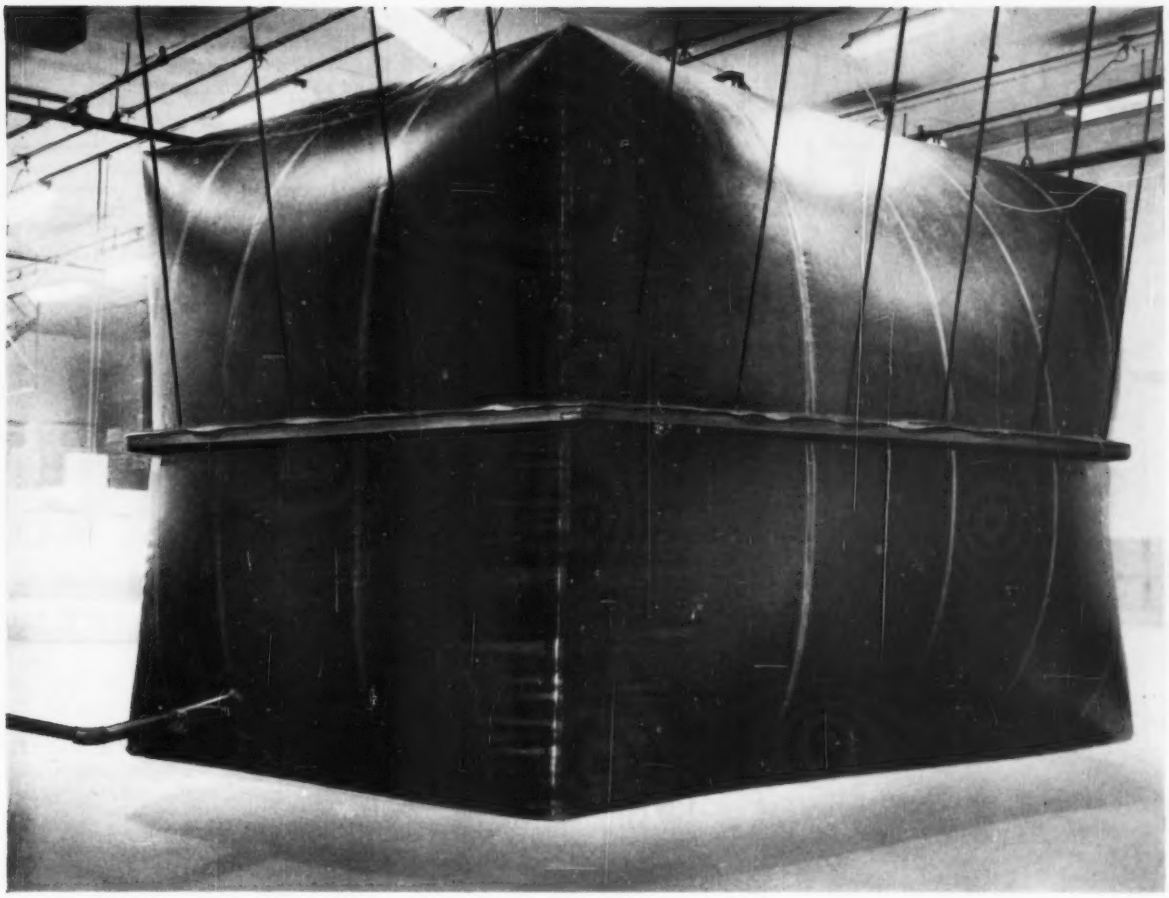
JONES & LAUGHLIN SUPPLY DIVISION has completed a new store building at Rangely, Colo. Located at 1060 Main St., it has been leased by J&L for operation as a supply store to serve customers in Northwestern Colorado.

A. O. SMITH CORP.'s former Meter, and Service Station Pump divisions and Erie Meter Systems Inc., which A. O. Smith acquired last Fall, have been merged to form the Smith-Erie division. Key personnel are **J. S. Thompson,** Erie, Pa., assistant sales manager; **J. W. Harris,** Houston, sales manager, engineered products; **C. P. Hammill,** Los Angeles, sales promotion manager; **L. G. Blumenberg,** Erie, service manager, and **R. L. Dull,** Erie, assistant service manager.

CLAUD S. GORDON CO. has elected **Robert H. Hoagland** vice president and general manager, Chicago. For five years he had been vice president of Aerovox Corp., New Bedford, Mass.

FOOD MACHINERY AND CHEMICAL CORP.'s Westvaco Mineral Products division has named **Edgar T. Dale** manager of its Los Angeles district office. For six years he had been Westvaco's sales representa-

For more data on advertised products, use Readers' Service Cards, last page.



STOP COSTLY VAPOR LOSS

with a Reeves Vulcan BREATHER BALLOON

. . . makes your storage tank a closed system

. . . can pay for itself in just 6 months!

Now save on vanishing vapors during gasoline and gas storage or transfer, or when your regular gas tank is shut down . . . with Reeves Vulcan Breather Balloons, the most efficient, low-cost system of vapor conservation ever developed. They require no skilled labor to install, no high-priced housing . . . cost practically nothing to maintain. Every Breather Balloon ever sold, here and abroad, is still in use . . . still returning profits. Not a single failure in over 12 years! For full details, write:

Reeves Brothers, Inc., Vulcan Rubber Products Division
1071 Avenue of the Americas, New York 18, New York

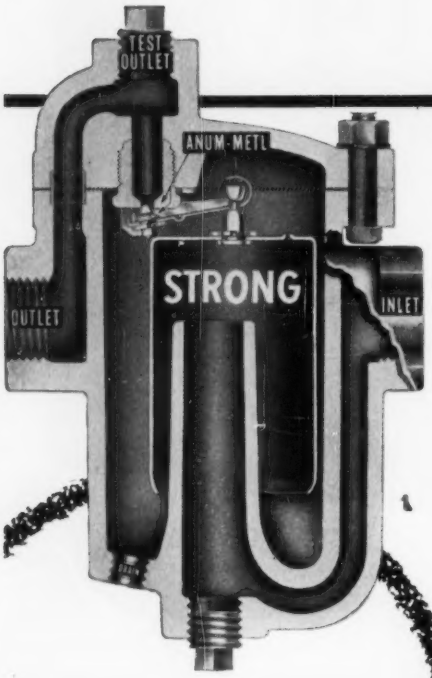
Another

REEVES VULCAN
RUBBER PRODUCT

For more data on advertised products, use Readers' Service Cards, last page.

STRONG HYDRO-FLEX

■■■ we engineered this new steam trap for YOU!



☐ Install Strong Hydro-Flex steam traps with assured confidence. This completely new line of low, medium, and high pressure steam traps will operate equally well on light and heavy condensate loads.

Hydro-Flex offers these outstanding features and more:

- greater discharge capacity and efficient operation under *all* conditions
- dual fulcrum arrangement that snaps the leak-free valve wide open to give unrestricted condensate flow
- all working parts and deep-drawn bucket of durable stainless steel.
- rugged construction features assure long trouble-free service.

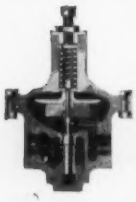
For complete information, contact your local Strong Distributor and write for new Bulletin No. SS-40A.

STRONG®
HYDRO-FLEX high efficiency under all condensate loads
STEAM TRAPS

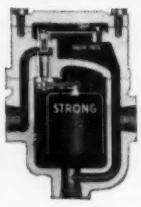
STRONG, CARLISLE & HAMMOND
508 SANDUSKY STREET
CONNEAUT, OHIO

Available from over 200 industrial distributors in the United States, Canada and Foreign Countries.

BOTTOM INLET SERIES
Hydro-flex traps with bottom inlet have the same high qualities and features as horizontal types.



PRESSURE REGULATING VALVES
3 types available for wide range application . . . to meet pressure and capacity requirements.



BLAST TRAPS
Thermal types for quick air and condensate removal during rapid heating up.

STRONG STRAINERS
Offer maximum protection from dirt, scale or sediment. Available in semi steel, cast steel and bronze.

tive in Southern California and Arizona. Earlier, he held sales and traffic positions at Westvaco's Newark, Calif., magnesia and phosphate chemicals plant.

HILLS-McCANNA CO. has appointed **Ernie Graves Co.**, Tulsa, exclusive representative for its diaphragm valves, replacement parts, metering and proportioning pumps and force-feed lubricators. The firm will represent Hills-McCanna in Oklahoma, Southern Kansas, and the Texas Panhandle.

Laverty

MacKendrick

CLARK BROS. CO. has named **F. W. Laverty** president. He has been executive vice president since 1953, and previously was sales manager. **J. N. MacKendrick** was appointed chairman of the board. He has been with Clark since 1928, and became president in 1953. He will continue to headquarter at Olean, N. Y.

MONSANTO CHEMICAL CO. has named **Dr. Quentin E. Thompson** a scientist. Formerly a research chemist, Thompson will have greater freedom to develop independent research programs. He has worked on a variety of exploratory research projects since joining Monsanto in 1951.

THE SWARTWOUT CO. has been awarded a Standard Vacuum Oil Co. instrumentation contract, for a refinery on Bataan Peninsula, the Philippines. The firm estimates the $250,000-contract to be "the largest of its type ever awarded by the petroleum industry."

BUCYRUS-ERIE CO., South Milwaukee excavator and drill manufacturer, plans to establish a research center at its Oak Creek, Wis., test ground. The first of a group of structures planned for the 125-acre site is being constructed by Permanent Construction Co., Milwaukee.

FOOD MACHINERY AND CHEMICAL CORP. has begun construction of a major addition to the Central Chemical Research laboratory, Princeton, N. J. The expansion, in the form of a new wing, will add more than 50 per cent to the laboratory floor space. Slated for use in February, 1960, the new section will cost around $1 million.

MINNEAPOLIS-HONEYWELL REGULATOR CO. is establishing fully staffed branch offices of its Datamatic division in New York, Los Angeles, Boston, Chicago and Washington, he said. In addition, a large staff of specialists at the main offices in New-

For more data on advertised products, use Readers' Service Cards, last page.

ton Highlands, Mass., will be available on special assignments to meet individual branch office or customer requirements.

WARREN PUMPS, INC. has named **Edward H. Elliott** industrial sales representative, Baltimore. His territory includes Maryland, Northern Virginia and Eastern West Virginia. He will headquarter at 419 Wyndon Road, Ambler, Pa., and maintain a branch office in York, Pa., headed by **George J. Wilkes,** 760 Woodberry Road.

H. K. PORTER CO., INC. has appointed **Robert F. Sutherland** sales representative in New York for the Refractories division. Previously with A. P. Green Fire Brick Co. for 17 years in the New York area, Sutherland will now service all types of refractories accounts.

MISSISSIPPI GLASS CO. has named **A. J. Tomasek** president and chief executive officer. He will continue as president, chief executive officer and board chairman of Walsh Refractories Corp., St. Louis.

SOLAR AIRCRAFT CORP. has named three sales firms representatives for industrial bellows and expansion joints. They are **Control & Steam Equipment Co.,** Seattle, Wash., **Huson Sales & Engineering Co.,** Spokane, Wash., and **Gene L. Towle,** Mexico City, Mexico.

CLARK BROS. CO. has named **Joseph J. Rosecky** executive vice president. A graduate of the University of Wisconsin, he joined Allis Chalmers Manufacturing Co. in 1924, and eventually became general works manager. In 1950, he joined Dresser Industries, serving first as a staff member for Clark in Olean, N.Y., and later as general manager of the Torrance, Calif., plant of Ideco Co., another Dresser division. From 1952-57 he was with the Baldwin-Lima-Hamilton Corp. as vice president and general manager, Eddystone division. Rosecky is a member of ASME and the Welding Engineers Society.

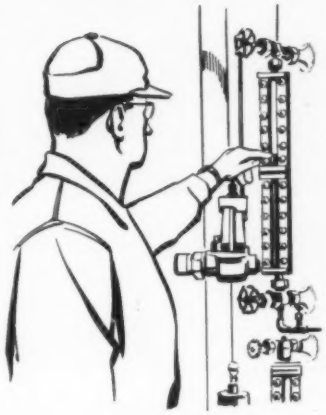
Rosecky

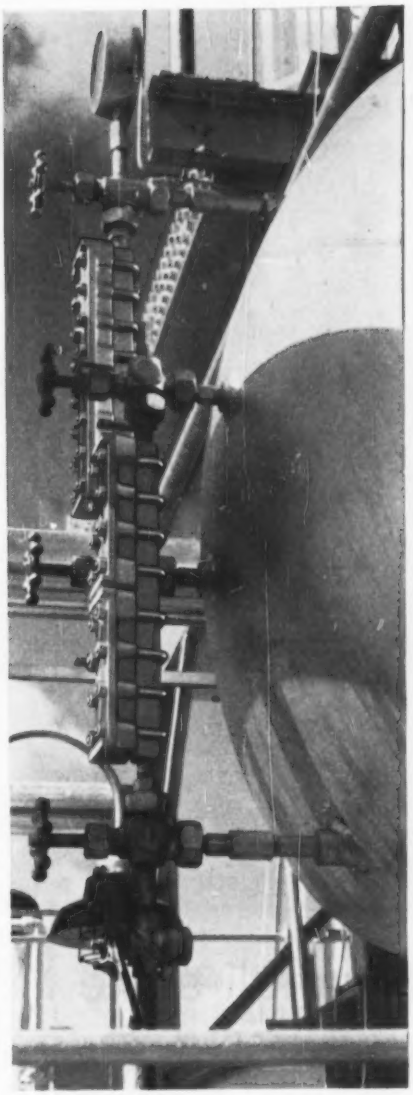
PITTSBURGH COKE & CHEMICAL CO.'s Protective Coatings division has named **John E. Himmelrich** Eastern regional sales manager. He will be responsible for East coast sales. Himmelrich previously had headquarters in Tulsa, where he represented division sales in the Central-West.

U.S. STEEL CORP. has named **J. Douglas Darby** vice president and assistant to the president. He has been an administrative vice president, commercial, of U.S. Steel. Holder of an A. B. degree from Yale University, he joined U.S. Steel in 1939.

ROCKWELL MANUFACTURING CO.'s Uniontown, Penn., plant has been awarded American Mutual Liability Insurance Co.'s "large certificate" safety plaque for the second time. The plaque is presented

It's easy to see why... Penberthy gages are preferred





● **PENBERTHY GAGES** on surge tank to gas treating plant of gas booster station. Natural Gas Pipeline Co., of America, Roberts County, Texas.

To be sure of clear, accurate liquid level readings... at temperatures from sub-zero to over 750° F. and to pressures exceeding 10,000 psi... simply specify Penberthy Gage Sets.

Used extensively for fluids ranging from water to highly corrosive and dangerous chemicals, Penberthy gages are available in a variety of materials including bronze, iron, carbon steel, stainless, monel, etc.... from stock or designed to specifications.

Exclusive construction features simplify maintenance, assure perfect alignment of frame with glass and gasket and permit servicing without removing assembly from vessel.

Request on your letterhead will bring you a copy of Catalog 36 detailing and illustrating complete line.

Everywhere... you're seeing more **PRODUCTS BY**

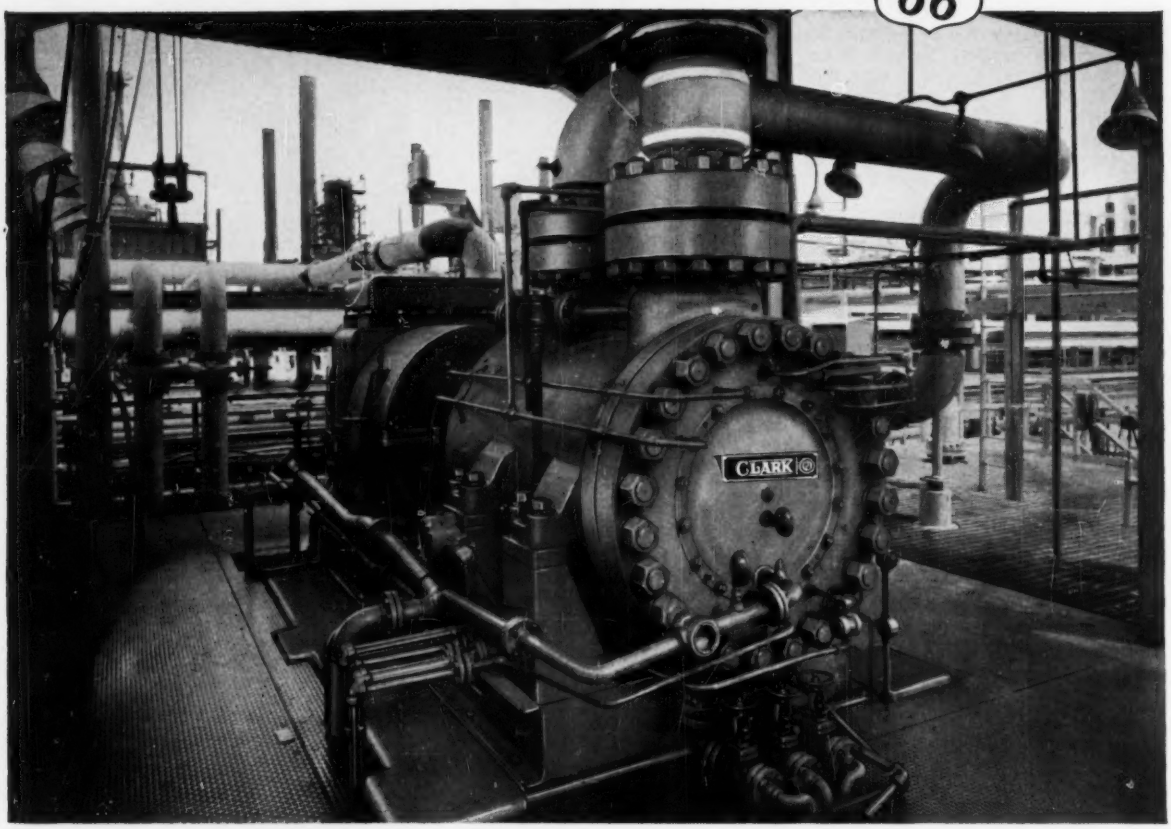
PENBERTHY MANUFACTURING COMPANY
Division of Buffalo-Eclipse Corporation
1242 Holden Avenue • Detroit 2, Michigan

PENBERTHY

- EJECTORS
- INJECTORS
- CYCLING JET PUMPS
- LIQUID LEVEL GAGES
- GAGE VALVES
- SUMP PUMPS

For more data on advertised products, use Readers' Service Cards, last page.

AT PHILLIPS PETROLEUM CO.



First full-scale PENTANE ISOMERIZATION plant uses Clark Barrel-Type Centrifugal Compressor

Isomerize normal pentane to permit the use of natural gasoline as a high octane blending stock? Why not, said Phillips Petroleum Company. Normal Pentane was one of the remaining major components of natural gasoline that could be upgraded. Furthermore, the low sensitivity of isopentane together with its high octane level made it an ideal blending agent in premium gasoline.

By-passing the usual prototype size unit, Phillips built the industry's first full scale pentane isomerization plant. The plant uses Universal Oil Products Company's Penex Process employing a platinum-containing catalyst. With a design capacity of 34,400 bbl. per day of pentane reactor feed, the plant can produce about 16,000 bbl. per day of 95% isopentane. Startup was smooth and design yields were quickly reached.

To handle the hydrogen recycle phase of the process at the Borger, Texas plant, a Clark Vertically-Split Multi-Stage Centrifugal Compressor was selected. While the ratio of hydrogen to hydrocarbon is low in this process, the high feed capacity requires 2,000 hp for hydrogen circulation. As in many other similar processes, the performance of this Clark compressor has from startup met the rigid design requirements.

CLARK

For complete details on Clark Vertically-Split Compressors, write for Bulletin 150.

COMPRESSORS AND GAS TURBINES

CLARK BROS. CO., OLEAN, NEW YORK

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

to any plant which turns in a record of 250,000 consecutive man-hours and 12 consecutive months without a lost-time accident.

DRESSER INDUSTRIES, INC., has named **James R. Brown, Jr.** director of manufacturing. He had been with Baldwin Lima Hamilton Corp. in Eddystone, Penn., since 1941. There, he was successively coordinator of industrial engineering, general superintendent for transportation products, manager of foundries, and works manager. At Dresser he will be responsible for evaluating manufacturing processes and procedures, analyzing capital expenditures, and making manufacturing recommendations, general business areas having to do with manufacturing among the Dresser companies.

Brown

DICK EVANS, INC. has purchased Industrial Weed Control Service of Abilene, with main offices in Wichita, Kans. **Louis May,** former owner and operator of Industrial Weed, has been appointed director of Dick Evans Inc., and will be sales engineer for the West Texas area. He will continue to office in Abilene.

TRACERLAB, INC. has elected **Robert A. Arrison** vice president for engineering, Keleket X-Ray Corp., a Tracerlab subsidiary. Arrison holds B.S. and M.S. degrees in electrical engineering from Massachusetts Institute of Technology. He was a project engineer in the X-ray division, General Electric Co. from 1947-56.

NORTON CO. has named **Jacob J. Walter** a refractories engineer. He will headquarter at the Philadelphia district office, and will cover the District of Columbia, Delaware, Virginia, Eastern Pennsylvania, and parts of Maryland and New Jersey. Walter received a degree in ceramic engineering from Iowa State College a year ago, and joined Norton as a sales trainee.

BAILEY METER CO. has opened a New Jersey sales office at 110 Halsted St., East Orange, N. J. It will be managed by **H. C. Wheaton,** who also manages the New York district office.

A. Y. McDONALD MANUFACTURING CO. has promoted **Fred J. Hagy, Jr.,** manager of the company's Waterloo, Iowa branch for the past 11 years, to merchandising manager. He will be responsible for the supervision of all branch operations, and will act as liaison between the branches and the home office, at Dubuque.

AMERICAN MARC INC., has received several military and commercial contracts totaling more than $1.6 million. The new contracts included production orders for diesel engines, generators and generator sets; and research and development contracts, approximately $470,000 for new products to be offered in the near future.

Petroleum Refiner Classified Ads

Petroleum Refiner New Classified Rates

RATES: Regular Classified (undisplayed) set in this type: 20 cents per word. Minimum charge, $4. Blind box address in our care counts six words. Replies forwarded without charge. **Display Classified ads,** set in suitably larger type with ruled border, $12.50 per column inch. Ten percent discount for two or more insertions of same copy in consecutive issues. **All Classified ads payable in advance.** Copy deadline: 25th of month preceding date of issue. Send copy and checks to: Classified Advertising, Petroleum Refiner, P. O. Box 2608, Houston, Texas.

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FOR SALE

2 OLIVER PRESSURE PRECOAT FILTERS
TYPE 316 S.S. VERY FINE CONDITION
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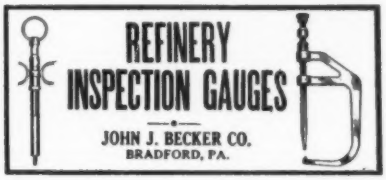


Be sure to read "New Equipment and Literature" Starting on page 358

WANTED

■ PETROLEUM REFINER back issues and files wanted to buy for cash, also other technical journals, P. R. Ashley, 27 East 21, New York 10, N. Y.

HELP WANTED

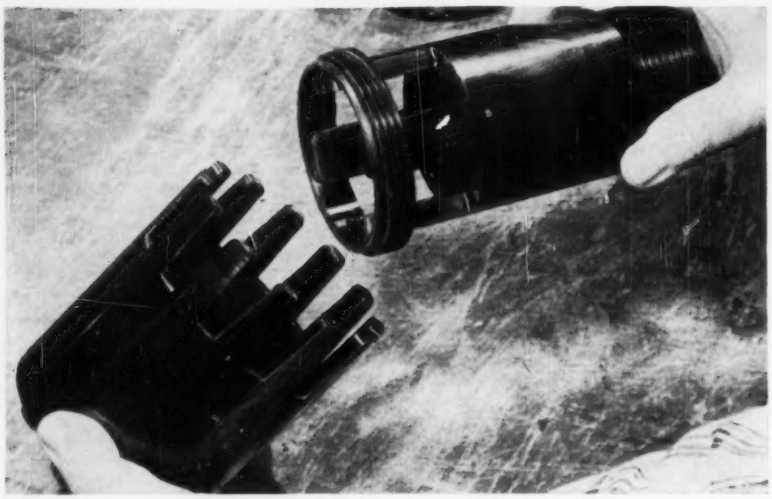
. . . Established Ohio asphalt refinery wants superintendent. Asphalt experience desirable though general refinery experience suitable. Excellent opportunity for right man. Respond Box 317-R, Petroleum Refiner, Houston, Texas.

INSTRUMENT SALES ENGINEER WANTED

Prefer Chemical Engineers with petroleum and process experience. Openings in St. Louis and El Paso. Mail reply to W. Messner, The Bristol Company, 434 Cotton Belt Building, St. Louis 2, Missouri.

Use Readers' Service Postcard on page 375 for more information on advertised products

New Equipment & Literature...



Plastic Bubble Caps Exceptionally Tough

Bubble caps and risers are being made from a thermosetting plastic material.

Although present production is restricted to caps and risers, the company plans to extend its output to include trays, downcomers and all of the other assemblies required for the distillation and treating processes of oil refining and petro-chemical manufacture.

One advantage of molded parts for tower internals is their lower cost. In part this results from the fact that production through molding lends itself to shapes and designs, which would involve intricate fabrication with stainless steel. Another advantage is that availability of molding permits the design engineer to gain exactly what his process demands without encountering excessive cost.

At present caps and risers are in production in sizes as large as 8 inches O.D. They are going into replacement, chiefly of more expensive machined carbon parts. Wyatt's Plastics, Inc.

Circle E1 green card, last page

New Catalyst Tougher Than Chrome Bead

Durabead cracking is exceptionally tough and produces less breakage than chrome catalyst. Because less catalyst needs to be added as "make-up" in the cracking unit, over-all catalyst costs are reduced.

In addition to the lower "make-up" necessary with Durabead, the pilot plant tests and subsequent experience gained in full-scale refinery operation have shown these other advantages of the new catalyst:

- A faster carbon-burning rate. This means that the capacity of cracking units previously limited by the regenerator is increased.
- A more valuable product distribution. Durabead produces 25 percent more gasoline for each pound of carbon formed on the catalyst.

Durabead catalyst's properties are superior to those of chrome bead because of an improved physical structure. The chemical composition of the two catalysts is the same. Durabead, however, is made by screening out the oversize and undersize beads, grinding the screenings to a very small size, and incorporating this ground material into the gel from which the beads are made. This process makes the finished beads exceptionally tough and resilient.

Another new catalyst, Heavy Durabead, is now being evaluated in commercial operation. This catalyst possesses all the advantages of Durabead, and, in addition, has a higher density. As a result, both the reactor capacity and the regenerator capacity are increased by about 50 percent over those formerly attainable with chrome bead catalyst. Socony Mobil Oil Co., Inc.

Circle E2 green card, last page

New Hydroisomerization Catalyst Developed

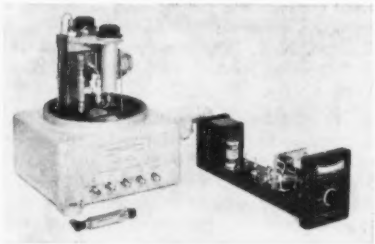
A metal-containing solid hydroisomerization catalyst (I-A catalyst) has been developed which has such enhanced activity and selectivity that it permits insomerization of light paraffins substantially to equilibrium at temperatures in the range of 200-500F. Provided are more favorable equilibria at these lower temperatures.

In continuous bench-scale operation, butane gives conversions of 60-64 percent per pass with isomerization efficiency of 96-98 percent; pentate is isomerized to give 77-78 percent per pass with a conversion efficiency of 98-99 percent and n-hexane yields as much as 39 percent dimethylbutanes per pass with 98 percent efficiency. The presence of naphthenes requires a somewhat higher isomerization severity, but does not otherwise interfere. Mixtures of pentanes and hexanes may be readily isomerized to give once-through product of 99 octane number (F — 1 + 3 cc. tel/gal).

The butane isomerization process has been pilot-plant tested to above 50 barrels of continuous throughput per pound of catalyst with little change in catalyst activity, and commercial plans are expected to be in operation in 1959.

Sulfur compounds lower the activity of the catalyst, but their effect is transient. Universal Oil Products Co.

Circle E3 green card, last page

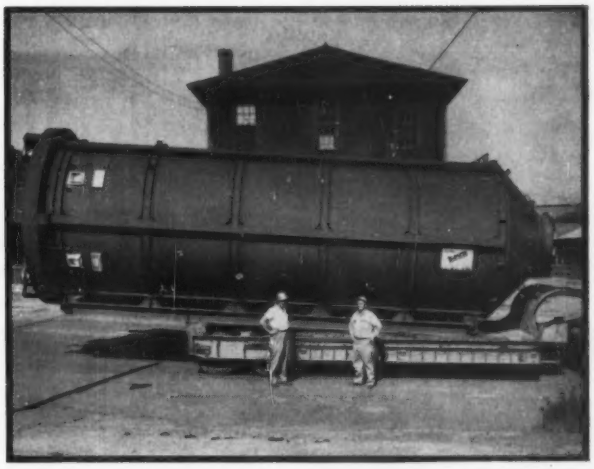


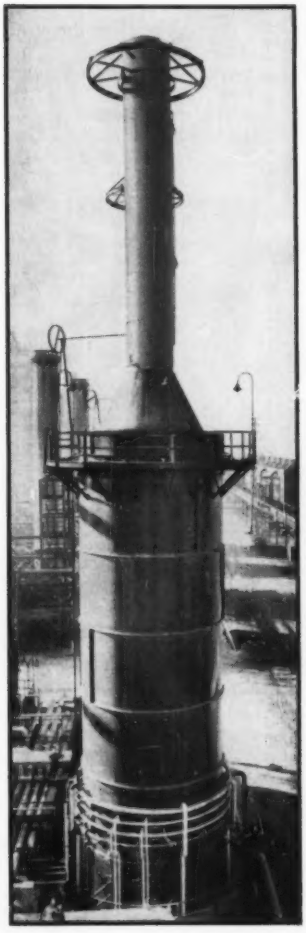
Automatic Moisture Control Possible With New Monitor

The new CEC 26-312 Moisture Monitor gives a continuous readout of the amount of moisture in many liquids. Quantities as small as one part per million can be detected immediately.

The instrument provides for the meas-

BORN BUILDS BETTER HEATERS

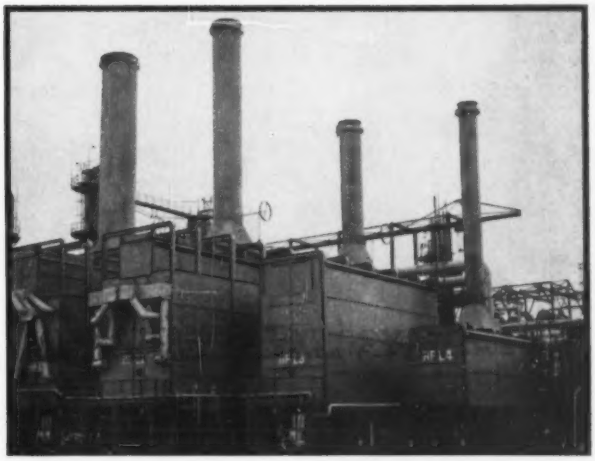




For one thing BORN builds nothing but heaters . . . heaters for every process heating requirement. For over forty-two years BORN has specialized in this field and as a result BORN HEATERS are known for their close control, economical, trouble-free operation plus exclusive safety features not found on any other heaters. During this time BORN HEATERS have built a reputation for producing day after day with no expensive "down-time" for frequent servicing and repairs.

No wonder BORN HEATERS are specified time and time again by clients whose names are the Who's Who of the Oil Industry.

For the complete story on a BORN HEATER to fit your needs, write, wire or call your BORN representative. He's anxious to serve you.



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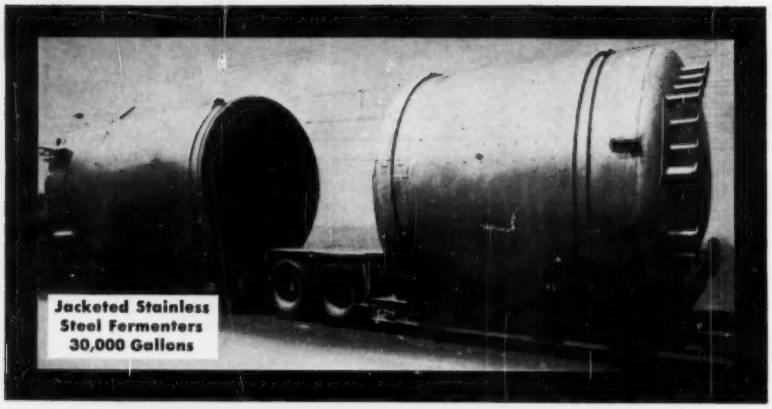
Manufacturers of Direct-Fired "UPFLO" Heaters
TULSA, OKLAHOMA

For more data on advertised products, use Readers' Service Cards, last page.

Koven IF MADE... IT'S WELL MADE!



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Koven equipment in all metals and alloys includes: High pressure vessels built to A.S.M.E. Codes; extractors; mixers; stills; kettles; tanks; stacks; breechings; hot transfer lines; large diameter fabricated piping and plate exhaust ducts; shop and field erected storage tanks.

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See Sweet's Catalog File and Chemical Engineering Catalog

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Koven FABRICATORS, INC.

93-P East Dickerson Street, Dover, New Jersey

Equipment . . .

urement and/or control of trace moisture in liquids. An important application is the monitoring of moisture in jet fuel. Another typical application is the instant detection of moisture in catalytic reformer feeds.

Besides making moisture detection and control quicker and more accurate, the continuous monitor opens the door to automation in controlling moisture content in liquids. This advancement is not possible with conventional wet-chemical procedures, which have the disadvantage of being squarely dependent on human operation in sample-taking, instrument reading, and adjustment. The new moisture monitor can signal the opening or closing of valves to maintain a precise addition or rejection of moisture. Because of its rapid response characteristics, the instrument will eliminate much complex controller mechanism and installation engineering time.

But even before the customer wishes to automate, the moisture monitor is now prepared to give visible or audible signals that the moisture level in a liquid is not within pre-determined bounds. Consolidated Electrodynamics Corp.

Circle E4 green card, last page

Field X-ray Possible With Portable 46½ lb. Unit

Field X-ray inspection of tanks, pipes and structure is a simple operation with new portable X-ray equipment.

Although weldments are normally radiographed at the tank construction site, a tank customer can now equip field inspectors with lightweight X-ray equipment which will contribute to a much higher degree of inspection intelligence.

The unit shown here is the new LX-140, which weighs only 46½ pounds. The control unit weighs only 25 pounds, and the entire unit is packaged in a shockproof case which measures only 26 x 24 x 18 inches.

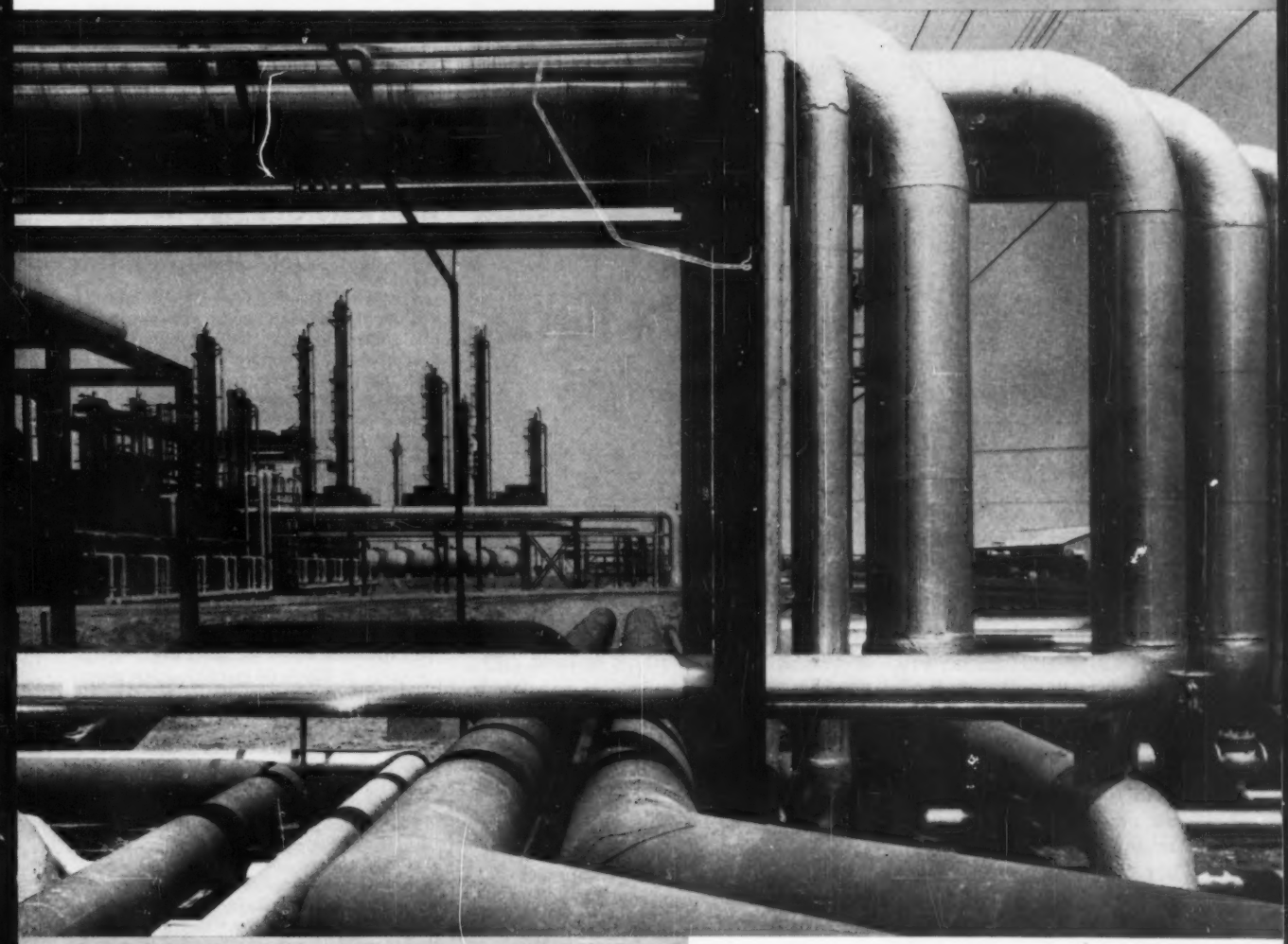
Simplified controls enable even the most inexperienced personnel to learn its operation with just a few minutes of instruction.

The unit offers a continuous range of 70 to 140 kvp. Radiographs with 2 percent sensitivity and 1.5 density can be produced

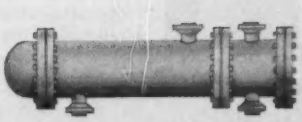
FAIR EXCHANGE: Acetic anhydride for "wash-'n-wear"

Due to their hydrophobic characteristics, synthetic fibers are increasingly popular in the "wash-'n-wear" market — with such organic chemicals as acetic anhydride as basic raw materials. Using their own direct oxidation process, with butane and propane as the normal charge, Celanese Corporation of America produces an entire series of these chemicals at its Pampa, Texas plant (below) . . . acetic anhydride, acetic, propionic and butyric acids, acrylate esters, vinyl acetate, acetaldehyde and methanol.

Western heat exchangers, performing with characteristic reliability and efficiency, have played an important role in heat transfer applications in the oxidation process at Celanese-Pampa since its initial construction in 1952.



The broadening experience of Western's engineering and technical staff in the petro-chemical industry is available to you for future heat transfer applications. We will feel privileged to serve you.



WESTERN

HEAT EXCHANGERS

WESTERN SUPPLY COMPANY

P.O. Box 1888 – Tulsa, Oklahoma

NEW!

LECTRODRYER® BUDGET AIR DRYER

supplies small quantities of dry air at low cost

If your requirements for very dry air are relatively small—but highly important—you'll find the new Budget Air Dryer tailor-made for your needs. An investment in large equipment is not needed. The Budget Dryer is modestly priced, easily installed and serviced, operates on any 110 volt a.c. line.

NEW BUDGET DRYER IS IDEAL FOR:

- air-operated instrument controls
- electronic equipment
- small cubicles
- pilot plant operations

This entirely new unit supplies up to 20 cubic feet per minute of air, dried to a dewpoint of −60°F or lower. Operation is completely automatic. Likewise, the unit is as foolproof as possible, operating independently of variations in air pressure. Rugged construction and a long operating cycle assure trouble-free use.

Lectrodryer Budget Dryers are standard units, available from stock, shipped ready for installation. For complete information on this new unit and its low cost, write for Bulletin B6A, Pittsburgh Lectrodryer Division, McGraw-Edison Company, 307 32nd St., Pittsburgh 30, Pa.

Lectrodryer McGRAW EDISON

Equipment . . .

with 1½ minute exposure through 1¼ inches of steel, according to the manufacturer. The new unit will operate in temperatures from 0 to 120 F, humidity up to 95 percent and altitudes to 5000 feet, and provides effective radiation protection. General Electric Co.

Circle E5 green card, last page

Electric Controller Has High Rate Of Response

An electrically operated modulating instrument (the Fultro-Lectric controller-positioner-valve combination) for controlling process pressures or temperatures enables the small plant to maintain precise control formerly possible only where a compressed air supply was available.

A change in the measured variable causes a switch assembly to actuate a shaded-pole, three-wire reversible motor, driving the valve in the proper direction. When the valve reaches the position called for by a small temperature sensing bulb, a feed-back switch quickly stops the motor.

The new unit offers a small temperature sensing bulb with high rate of response; adjustable proportional band; positive valve positioning; easy installation; one inch stem travel; reproducible temperature setting; field reversibility and manual valve positioning. Robershaw-Fulton Controls Co.

Circle E6 green card, last page

Barrel-Type Pump Designed For Refinery Processes

A new barrel-type pump designed especially for refinery process and other high-pressure services is available.

Classed as the CMR charge pump, it features double-case, barrel-type construction with proven "Unit-Type" rotor assembly. The double-case construction is a safeguard against leakage of volatile fluids through joints, because the symmetrical design provides greater strength and minimizes thermal distortion.

Since the charge pump is designed and constructed of materials to withstand heavy-duty service they can be and are operated without a spare . . . For utmost reliability, the CMR is built with forced-

feed lubricated sleeve radial bearing and Kingsbury thrust bearing.

This new pump is a vertically-split double-case, multi-stage unit, built in 1½ and 2½ inch discharge sizes, with capacities up to 400 gpm, pressures to 1500 psi and temperatures to 750 F. Ingersoll-Rand Corp.

Circle E7 green card, last page

Bulletin Covers Reclaiming Scrap Parts Economically

Cleaning procedures that make it economical to reclaim scrap parts are detailed in a new bulletin just published. The booklet, third in a series of refinery maintenance bulletins, deals specifically with salvage and plant housekeeping. It points out that cleaning represents at least 50 percent of salvage operations. Describing two compounds which remove grease, oil, rust, and paint in one simple soaking application, the bulletin gives specifications for construction of the salvage tank, including drawings, copies of which are available from the company. It tells how to prevent rusting after cleaning.

Other subjects covered by the 12-page booklet include cleaning steam turbines, removing scale and carbon from compressors, cleaning vacuum filters, painted equipment, electric motors, tank cars, barges and tank trucks. Oakite Products, Inc.

Circle E8 green card, last page

BTU Meter Measures Heat Transfer In Liquid Streams

A new low priced mechanical BTU Meter accurately measures heat transfer to or from a liquid stream in many industrial processes and air conditioning systems.

The Model 200 BTU Meter multiplies temperature change of the water by the flow, and two counters register the heat transferred and the liquid flow. Indication of differential temperature is provided.

The BTU Meter may be located up to ten feet away from the flow measuring element, in a position convenient for reading and checking. Any liquid volume above 0.25 gpm can be metered. American Meter Co.

Circle E9 green card, last page

Brochure Tells Application Of Spectrophotometers

A comprehensive, 20-page brochure titled "Selecting Instruments to Solve Your Analytical Problems" has been published.

It discusses applications of instrumental analysis and its advantages. It specifically tells how and why infrared and ultraviolet spectrophotometers and gas chromatography instruments are used and the benefits obtained with them. Typical spectra and runs, and instrument schematics are used.

The brochure gives details of the company's complete line of analytical instru-

Absolute Line Shut-off

BY ONE MAN – IN ONE MINUTE!

HAMER *Visible Shut-off*

LINE BLIND VALVES

Hamer Line Blinds are unsurpassed for positive action, easy operation, long-life service and lasting safety. One man can open or blind a line in less than one minute, and there is nothing like a solid plate for a PERMANENT LEAKPROOF SHUT-OFF. Bar or handwheel operation eliminates wedges, hammers, wrenches needed for spreading conventional flanges. Removes fire hazard of sparking and stops damage to equipment.

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Will not stick or freeze. Perfect for hard-to-hold fluids. Simple plug adjustment nut eliminates sticking

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Representatives throughout the World

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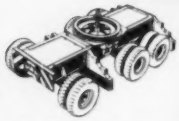
For more data on advertised products, use Readers' Service Cards, last page.

RUBBER-TIRED *Maxi carrier speeds travel time between jobs and eliminates the damage to road surfaces by crawler cranes, yet is more maneuverable in the tight spots than a truck.*

FULL 360° SWING, *plus short turning radius of Maxi carriers permits "pin-point" load placement.*



EXTRA WIDE *Maxi carriers increase load capacity when traveling up to 25% over either truck or crawler mounted cranes.*

LOW COST OPERATION. *One engine and one operator controls all functions of both crane and carrier, eliminating need of truck driver. No costly crawler maintenance with a Maxi.*

SEE YOUR LOCAL CRANE DEALER OR WRITE DIRECT TO: THE MAXI CORPORATION
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Ask your nearby Panalarm sales engineer to show you why Universal Series 50 is the petroleum industry's No. 1 annunciator choice . . . how its adaptability and reliability can help increase your profits . . . by producing maximum information and reducing costly downtime. No obligation, of course.

Write for Catalog 100 B today.

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Division of
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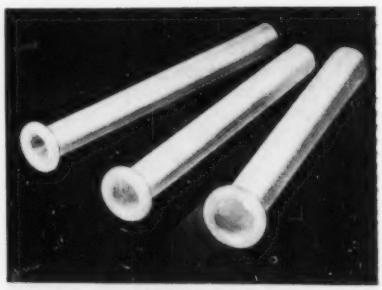
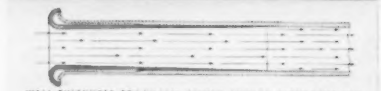
Equipment . . .

ments and accessories, and their applications. It also discusses briefly how infrared and gas chromatography can be used in conjunction to obtain a complete analysis. Perkin-Elmer Corp.

Circle E10 green card, last page





WALL THICKNESS GRADUALLY TAPERS TOWARD DISCHARGE END. ASSURES SMOOTHEST POSSIBLE WATER FLOW. ELIMINATES TURBULENCE

Plastic Exchanger Tube Inserts Prevent Erosion

Condenser and heat-exchanger tube protectors molded from fracture-proof plastic are available in an exclusive construction that prevents turbulence. This smooth flow is accomplished on the protector's inner wall, which gradually tapers toward the discharge end, providing the thinnest possible wall at that point. Thus, the extremely close conformity of the protector end with that of the tube's I.D. allows smooth water flow.

These new protectors are named "John Crane" Plastic Tube Protectors and are available in three plastic materials, the user having his choice of nylon, polyethylene or phenolic resin. They positively prevent erosion and abrasion and are easy to install on tubes. The new protectors are intended to help reduce costly tube maintenance and replacement by protecting tube ends for the life of the tube. Crane Packing Co.

Circle E11 green card, last page

Aluminum Pipe In Schedule 40 Equivalents Available

A new thick-jointed aluminum pipe is now available in a complete range of Schedule 40 equivalent sizes.

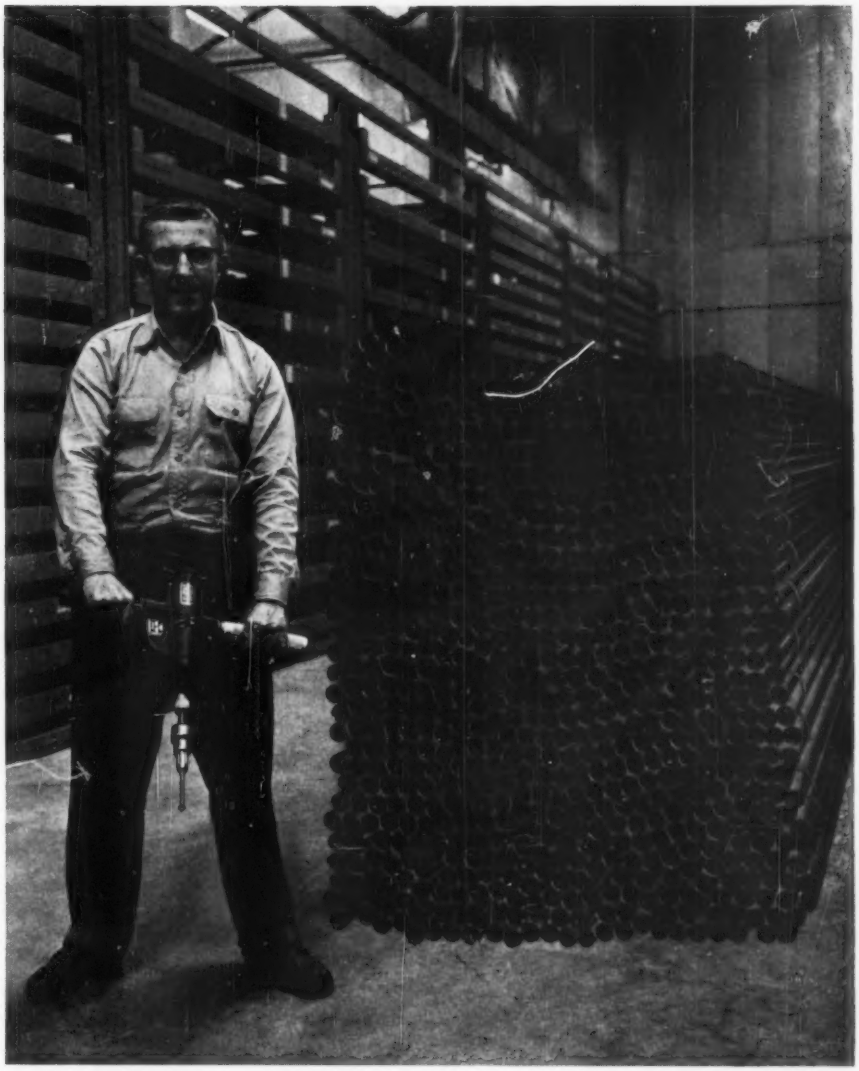
The Schedule 40 equivalents are in addition to Schedule 80 equivalent sizes obtainable when the product was introduced last December.

The new sizes are being produced in response to requests from oil, chemical and processing firms which want to extend the cost-saving features of the pipe to their operations.

The walls of the heavy-end pipe are tapered in thickness to provide extra strength at the joints while eliminating excess metal in the pipe body. Available in 30 and 40-foot lengths, it can be used interchangeably with other standard aluminum pipe.

A brochure containing full information

with AIRETROL, he can roll all these tubes in 1½ hours



There are 720 tubes (1½" dia.) stacked beside the maintenance worker in the photo above. Your maintenance crews can do just as well, without extra effort, when equipped with Airetrol automatic tube expansion control.

Here's why. With Airetrol, the operator merely dials the tool's micrometer head to the desired torque in ft. lbs., and starts to work. A precision torque sensing mechanism automatically stops tube expansion at this setting. Accuracy? Within .001" every time. As a result, it's no trouble for operators to roll 12 tubes per minute consistently.

YOU GET THIS SAME HIGH RATE OF PRODUCTIVITY with all Airetool tube maintenance equipment. For example, Model CC-475 tube cleaner, with built-in flushing system, cleans hardest deposits from 1" dia. tubes fast. Yet, tool weighs only 10 lbs. One man easily handles it without supporting rig . . . moves quickly from job to job. IT TAKES TIME-SAVING AIRETOOL TOOLS LIKE THESE TO CONSTRUCT AND MAINTAIN A MODERN OIL REFINERY. Write for tubular maintenance equipment Bulletin No. 66.

AIRETOOL
MANUFACTURING COMPANY
SPRINGFIELD, OHIO

30 years experience in pneumatic tools

BRANCH OFFICES: New York, Chicago, Tulsa, Philadelphia, Houston, Baton Rouge
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CANADIAN PLANT: 37 Spalding Drive, Brantford, Ontario
EUROPEAN PLANT: Vlaardingen, The Netherlands

See our 28-page insert in The Refinery Catalog

For more data on advertised products, use Readers' Service Cards, last page.

CLEVELAND
Has the Answer to All Wire Cloth Problems

Whether your problem is bulk or fabricated parts, filtering, straining, screening or catalyst, get in touch with Cleveland. Over 40 years experience in the weaving and fabrication of industrial wire cloth provides the answers to your screen problems.

Immediate shipment of many standard meshes or weaves from stock. Fabrication into products is our engineering specialty.

SEE OUR AD IN REFINERY CATALOG

Send your specifications or call today. We'll be glad to consult with you on your wire cloth problems without delay. Ask for Bulletin No. 10.

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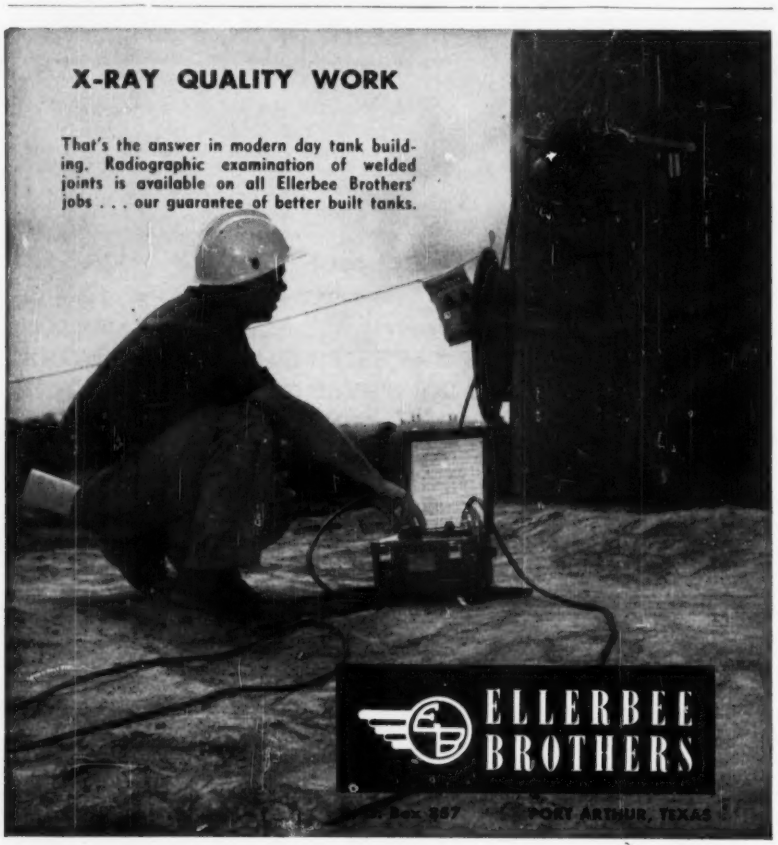
3571 EAST 78th STREET, CLEVELAND 6, OHIO • DI 1-1832


X-RAY QUALITY WORK
That's the answer in modern day tank building. Radiographic examination of welded joints is available on all Ellerbee Brothers' jobs . . . our guarantee of better built tanks.
ELLERBEE BROTHERS

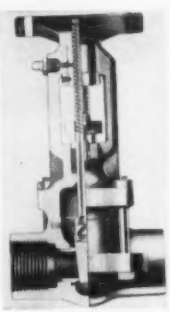
Equipment . . .

on both Schedule 80 and 40 equivalents of "H-E Pipe," including data on wall thicknesses, pressures, weights and alloys, is available. Reynolds Metal Co.

Circle E12 green card, last page

Ductile Iron Gate Valve Available In Small Sizes

A new line of ductile iron gate valves in sizes of ½ to 2 inches is in production.



The newly designed valve is the first to utilize all of ductile iron's unique properties and specific advantages. Consistently high quality castings are assured through strict controls and exacting ductile iron foundry procedures. The valve, listed in the company's specifications under the name "Pipe-Pal" is rated at 1,000 psi for all temperatures from —20F to 650F.

The new product has a spread flange design which embodies longer bolts that store extra bolting energy to prevent joint loosening. Ductile iron's strength, as well as its excellent thermal shock and impact resistance, render it ideally suited for refinery and process lines. This function was formerly restricted to higher cost steel valves.

Other advantages of the ductile product include corrosion resistance and processing advantages leading to manufacturing economies. Ohio Injector Co.

Circle E13 green card, last page

Brochure Covers Small General Purpose Valves

A four-page brochure covering a line of small valves for general application has been released.

Information pertaining to working pressures, specifications, construction features, and suggested applications has been included in this compact work. Users will find it a valuable and practical source of reference. Kerotest Manufacturing Co.

Circle E14 green card, last page

Plastic Piston Rings Last 20 Times Longer Than Iron

Self-lubricating plastic piston rings for compressors that last more than 20 times as long as conventional cast iron rings when exposed to wet hydrogen, and with a single ring taking the place of four of its metal counterparts, have been developed.

Fabricated from a reinforced "Teflon" TFE-fluorocarbon resin, said to be slipperier than ice, the plastic rings easily withstand pressures as high as 4,500 psi and perform well over a wide temperature range—from minus 320 F, where conventional lubricants required with metal rings are useless, to 500 F, where common lubricants degrade or vaporize.

Field tests in compressors, where piston

rings are exposed to highly corrosive wet hydrogen, indicate the plastic rings are good for at least 2,000 hours of service compared with the ordinary 100-hour maximum life of cast iron rings. In the same tests, six rings of a "Teflon" resin were found to be sufficient for compression in a piston that formerly required as many as 26 cast-iron rings. In addition, the plastic rings required no fluid lubrication, eliminating the danger of gas contamination that often is caused by lubricants which must be used with cast iron rings. E. I. du Pont de Nemours & Co.

Circle E15 green card, last page

Book On European Steel Fabrication Released

A beautifully prepared, hard back book by the Italian steel fabricating firm, Guido Sartori Co., has been made available to the readers of Petroleum Refiner.

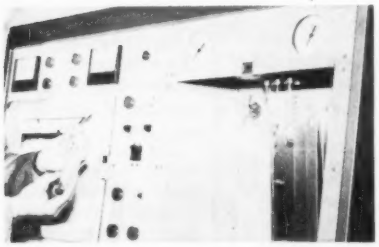
It is complete with full color photographs of the company's plant in Venice. It also contains some unusual European construction photographs. Guido Sartori Co.

Circle E16 green card, last page

Card Gives Pipe Data On 1/8 Through 36-Inch Sizes

Engineers, buyers and others involved in purchasing of pipe will be interested in a new technical data card just published. This card contains the dimensions and weights per foot of pipe in sizes 1/8 through 36 inches for all schedules. Babcock & Wilcox Co.

Circle E17 green card, last page



Chromatograph May Help Improve Synthesis Yields

A commercially practical preparative gas chromatograph has been developed.

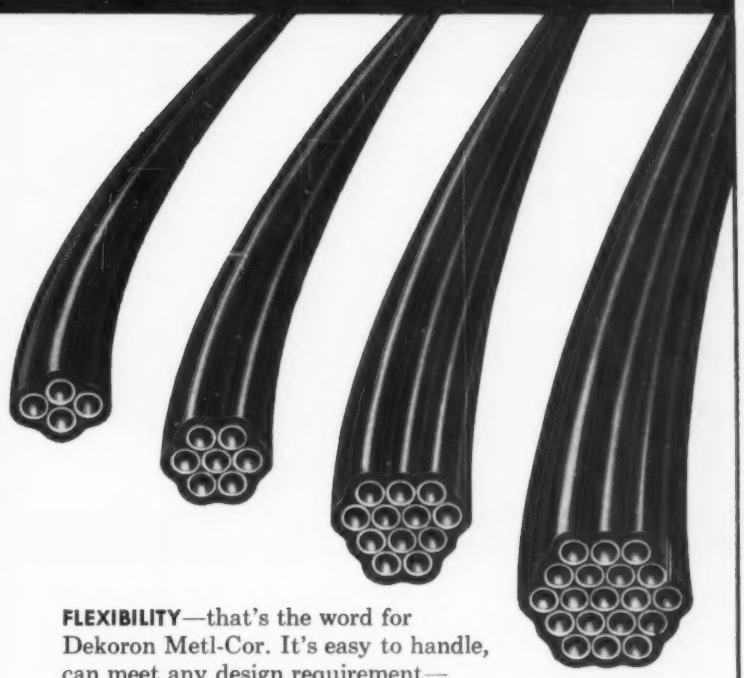
The Megachrom departs from recent developments in gas chromatography, which have emphasized smaller and smaller samples, the instrument uses the separatory power of chromatography to fractionate and collect samples of ultra pure materials in volumes 100 times *larger* than possible with existing chromatographs with no sacrifice in resolution. This makes available sizeable quantities of ultra pure materials which before have been barely visible or seen only as traces on a recorder chart.

Studies on by-products of organic synthesis in chemical and protroleum industries will be possible because of the separation of ultra-pure materials. This will permit investigation of the reactions in order to learn how to improve synthesis yields.

Hydrocarbons studies will be possible

DEKORON METL-COR MULTIPLE TUBE HARNESS

cuts installation costs
bends without distortion
solves instrument line corrosion problems



FLEXIBILITY—that's the word for Dekoron Metl-Cor. It's easy to handle, can meet any design requirement—and it's highly corrosion resistant, too.

FIRST, Metl-Cor's exclusive Extru-Loc construction makes it easy to bend with no tube distortion.

SECOND, the Metl-Cor design is flexible. You can specify Metl-Cor with core tubes in either copper or aluminum . . . in any standard or special OD or wall thickness . . . with almost any number of tubes in each bundle.

MOST IMPORTANT, no matter which type or size you specify—you get all the inherent cost-cutting savings and longer life that you pay for.

AA-7511

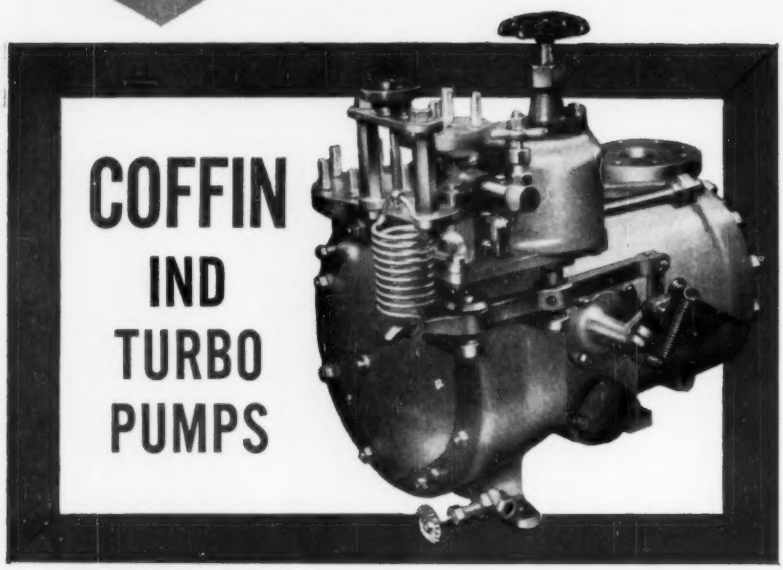
Dekoron Tubing is available in many other forms: Dekoron Poly-Cor; M-Ribbon; P-Ribbon; Protecto-Pac; Armored Poly-Cor and Metl-Cor; and single-line Dekoron Tubing.

Dekoron products
QUALITY · RESEARCH · SERVICE

SAMUEL MOORE & COMPANY
DEKORON PRODUCTS DIVISION • MANTUA, OHIO

For more data on advertised products, use Readers' Service Cards, last page.

Complete Pump, Turbine and Controls



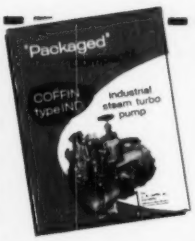
PACKAGED — integral design of the IND Pump results in a compact, highly efficient unit which mounts impeller and turbine wheel on a short, rigid shaft. The unit is equipped with complete controls for constant or differential pressure regulation.

APPLICATIONS — compact and highly efficient, the Coffin type IND Steam Turbo Pump is designed for General Boiler Feed or any other pumping service where medium volume and high pressure is required.

SPECIFICATIONS-

Capacities	to 180 GPM —	Height 32"
Discharge Pressures	to 350 PSIG —	Width 25"
Liquid Temperatures	to 300°F —	Length 32"

For special installations these ratings may be exceeded.



Coffin Turbo Pump Co.
326 South Dean Street, Englewood, N. J.
Gentlemen: Please send me illustrated booklet further describing the Type "IND" Pump.

Name _____
Position _____
Company _____
Street _____
City _____ Zone ____ State _____

COFFIN TURBO PUMP CO.
FOOD MACHINERY AND CHEMICAL CORPORATION
326 South Dean Street • Englewood, New Jersey
Agents in all Principal Cities • Cable Address: COFCO

Equipment . . .

because of this ability to separate quantities of materials. An example is in the separation and investigation of the hydrocarbon components of gasoline. Beckman Instruments, Inc.

Circle E18 green card, last page

Cork and Silicone Rubber Makes New Gasket Material

Formulation of a new compound combining cork and silicone rubber has just been announced.

This unique material, known as LC-800, combines the advantages of cork with silicone rubber. It now allows the gasket designer to use cork and rubber gaskets at much higher temperatures than heretofore possible.

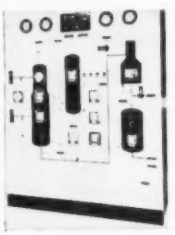
In addition to extending the temperature range of cork and rubber materials, the compound is considerably less expensive than straight silicones.

It can be made in ribbon and lathe cut rings, both extruded and laminated, as well as mats, sheets, and die-cut parts. Armstrong Cork Co.

Circle E19 green card, last page

Magnesium Panel Boards For Easy Field Alteration

A new line of lighter weight magnesium control room panel boards which are easier and safer to alter in the field is available. Besides lighter weight, magnesium panels permit substantial savings in time, effort and cost when installing additional instruments or making other panel alterations in the field. The need for blow torch cutting or welding during alterations is completely eliminated, providing for greater safety in hazardous atmospheres. Panels can be faced on one or both sides with 1/16 inch sheet Formica or Mylar, as required. Panellit, Inc.



Circle E20 green card, last page

Titanium Pumps And Valves Manufactured To Order

Centrifugal pumps and valves made of commercially pure titanium are now being manufactured to order.

The new titanium pumps and valves were developed to meet the ever-increasing need for more corrosion resistant equipment in the chemical industry. The pumps will be available in sizes from 1 inch x 1 inch and capacities from ½ gpm. Durco Type K, "Y" valves, with all parts in contact with the corrosive solution fabricated from Mallory-Sharon titanium, are available in a size range of 1 inch through 4 inches. Non-lubricated and non-sticking Durco Type "F" plug valves, fabricated

PREDICTION: There's a WALSH Refractory Castable in your Production Picture

Assurance Of New Highs In Performance At Lower Cost

Whether your refractory castable practice calls for a two-component lining or consideration of a "one shot" system later on, you'll find the right Walsh product for your purpose. Modern as tomorrow, every Walsh Castable offers absolute homogeneity—the result of production control methods that insure the perfect union of all ingredients for efficient service throughout a longer life. The whole money-saving story is available from your nearest Walsh representative. Or, write us direct, today.

WALSH EXTRA STRENGTH H & B CASTABLE (Service Type) For highly abrasion-resistant, monolithic, working linings in catalytic regenerators, reactors, and other refinery equipment.

WALSH LITE WATE INSULATING CASTABLE NO. 50. Features high bulk density while retaining a low K factor. Recommended for backup use in two-component linings.

WALSH LITE WATE INSULATING CASTABLE NO. 70. Higher strength and a low K factor makes this insulating castable highly desirable for "one shot" linings.

All Walsh Castables are characterized by extreme "flowability", excellent nozzle compaction, lower rebound loss . . . plus greater strength, better bond . . . throughout the complete temperature range.

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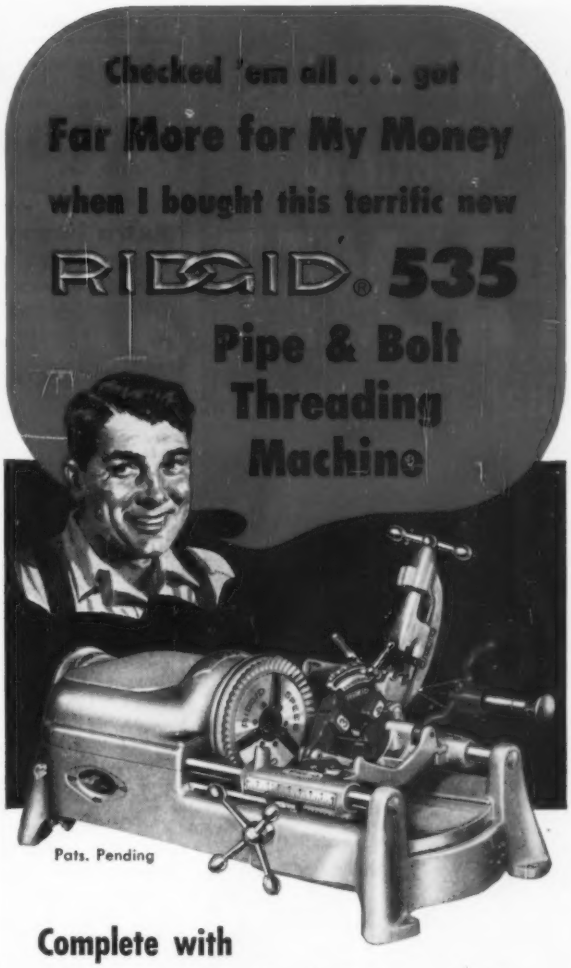
Specialists in Refractories of High Bulk Density and Low Porosity



Complete with 1 Universal Die Head, 2 Sets of Dies for ½" to 2" pipe or conduit

Looks good, does better. Perfect cutting, reaming, threading fast . . . and easy! Three tools operate independently . . . swing up out of the way for short pipe chucking from front. Slip-proof Speed Chuck is a great performer. Concealed oil system, automatic shut-off nozzle. Quick-opening die head sets to size right in machine. Power?. . . RIDGID-built motor handles 2" pipe, conduit, bolt, rod—and 12" geared tools easily. Try it, compare it . . . and you'll understand its enormous popularity! Leg and wheel stands available. At your Supply House.

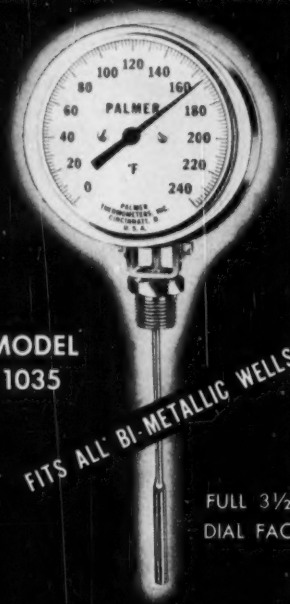
The Ridge Tool Company Elyria, Ohio, U.S.A.

THREADED PIPE . . . *It's Tight . . . It's Best . . . Costs Less!*

Outstanding Accuracy

PALMER

Dial Thermometer



Check these functional features

- Direct-drive Bourdon Coil with a filled system for longer lasting accuracy.
- Stem can be placed at any desired angle and case can be rotated to most readable position.
- External calibration for zero setting.
- Unaffected by stem alignment.
- Accurate to one scale division.
- No sticking at any temperature.
- Non-corrosive case.

PALMER

THERMOMETERS, INC.

Mfrs. of Industrial Laboratory, Recording and Dial Thermometers

2515 Norwood Ave., Cincinnati 12, O.

Equipment . . .

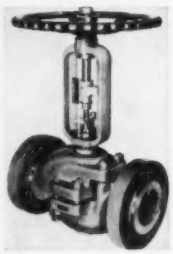
from titanium are also available in sizes of ¼ inch through 3 inches.

This equipment is designed in titanium specifically for the highly corrosive environments found in chemical plants. The Duriron Co.

Circle E21 green card, last page

Extra Heavy Handwheel Operated Control Valves

A new line of handwheel operated control valves, designated as Series LM valves, is available.



The valve features a single-seated valve body with extra thick body walls cast to 600 pounds ASA rating. It is available in ductile iron, steel, bronze, and many high alloys, and is especially suited to solve corrosion and erosion problems encountered when using "hard - to - handle" process fluids. Tight shut-off is guaranteed through the use of special seat materials such as teflon. A complete range of sizes, ¾ inch through 6 inches, with separable or integral flanges, is available. Microflow control is accomplished by the combination of a vernier position indicator, long stroke, and an oversized handwheel. Other features are a fully guided throttle plug for positive alignment, and a "lift-out" seat ring design. Split valve body allows quick disassembly for inspection and maintenance.

Should fully automatic or remote manual operation be desired, the valve can easily be converted in the field by mounting a pneumatic cylinder or spring and diaphragm actuator. Conoflow Corp.

Circle E22 green card, last page

Maintenance Bulletin Tells How To Reclaim Scrap Parts

Cleaning procedures that make it economical to reclaim scrap parts are detailed in a new bulletin just published. The booklet, third in a series of refinery maintenance bulletins, deals specifically with salvage and plant housekeeping.

The bulletin points out that cleaning

Dependable

SACHSE ELECTRIC INC.

BATON ROUGE LA.

For Immediate Service

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BLINDS • SPACER RINGS • TEMPORARY and LINE STRAINERS • PIVOT FLANGES

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The MACK IRON WORKS COMPANY

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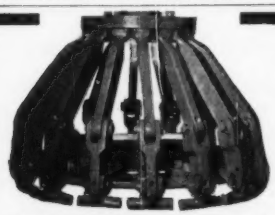
WRITE TODAY FOR CATALOG A-9



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Filling and Crimping Equipment

for handling greases and other viscous fluids.

- No operator required.
- 100% air operated.

Fills, seals, stamps and counts lug cover pails. Output of 15 pails per minute. Write for details on installation to meet your requirements.

BARRETT Manufacturing Co.

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REFRACTORY HAYDITE

Makes Higher Heat Resistant Concrete

Haydite aggregate used with Lumnite cement produces refractory concrete suitable for sustained temperatures up to 1800-2000° F., which makes it excellent for tubular heaters, ducts, flues, stacks and catalytic crackers. Weighing from 30 to 40 per cent less than ordinary aggregate concrete, Haydite is exceedingly strong. It has excellent insulating properties and withstands pressures of up to 1130 pounds per square inch. Write today for free folder and complete information about Carter-Waters Refractory Haydite.

We sell direct to you.

CONSTRUCTION MATERIALS

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2440 Pennway Phone GRand 1-2570

Equipment . . .

represents at least 50 percent of salvage operations. It describes two compounds which remove grease, oil, rust, and paint in one simple soaking application. It gives specifications for construction of the salvage tank, including drawings, copies of which are available from the company. It tells how to prevent rusting after cleaning.

Other subjects covered by the 12-page booklet include cleaning steam turbines, removing scale and carbon from compressors, cleaning vacuum filters, painted equipment, electric motors, tank cars, barges, and tank trucks. Oakite Products, Inc.

Circle E23 green card, last page

Brochure Covers Details Of Ballast-Type Trays

A brochure giving detailed information, specifications and engineering data on a line of ballast-type trays is available. The brochure describes trays manufactured under the Glitsch license by the manufacturer, which specializes in stainless steel fabrication. Metal Propellers, Ltd.

Circle E24 green card, last page

Orifice Union's Contoured Plate Eliminates Gasket

A new line of forged carbon steel, beveled orifice unions, designed to join sections of pipe and at the same time help measure and control the flow of liquids or gases under pressure has just been announced.

Orifice unions perform metering, measuring and now control.

A new beveled orifice plate has been designed for the new unions. The stainless steel plate is shaped to fit the contour of the union seat and eliminate gaskets. It snaps into place automatically as the union is tightened.

Extending from the steel disc is an identifying steel tag with the diameter of the orifice hole marked on it. Holes can be drilled to a minimum diameter of 1/64-inch.

The new beveled orifice unions are available in all sizes from ¼ through 2-inch pipe sizes. Working pressures for steam, water, oil, vapor, ammonia, chemicals, or air range from 3,000 pounds at 100F to 925 pounds at 900F. All parts are precision machined. Union nuts are permanently lubricated by cadium-plating for heavy duty use on severely corrosive surfaces. Clayton Mark and Co.

Circle E25 green card, last page

Chart Compares Various Protective Coating Systems

A new four-page chart "Comparison of Maintenance Coating Systems," designed to aid all engineers and maintenance personnel concerned with buying and specifying corrosion resistant maintenance protective coatings has been released.

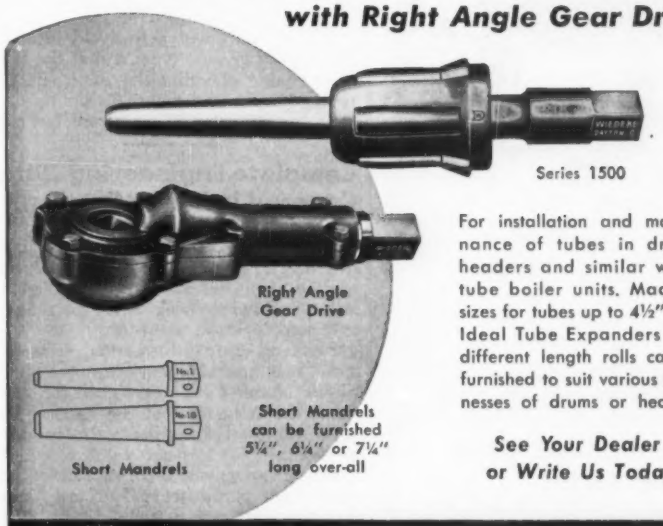
The chart compares 17 standard systems

IDEAL

for more Speed and greater Efficiency

Series 1500 Tube Expanders

with Right Angle Gear Drive



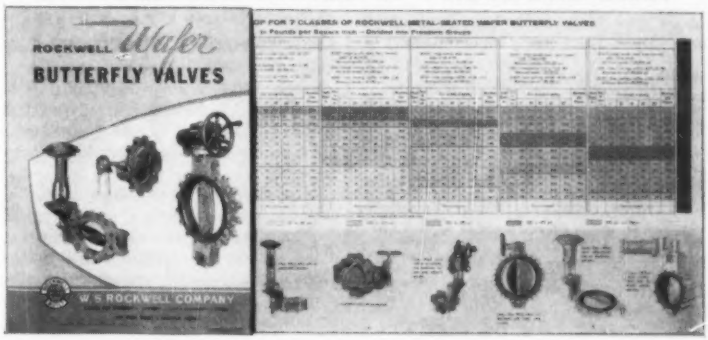
For installation and maintenance of tubes in drums, headers and similar water tube boiler units. Made in sizes for tubes up to 4½" O.D. Ideal Tube Expanders with different length rolls can be furnished to suit various thicknesses of drums or headers.

See Your Dealer or Write Us Today!

THE GUSTAV WIEDEKE COMPANY
DAYTON 1, OHIO

NOW! SELECTION MADE EASY

OF THE *"WAFER"* BUTTERFLY VALVE YOU NEED FOR REQUIRED RANGE OF PRESSURE DROP

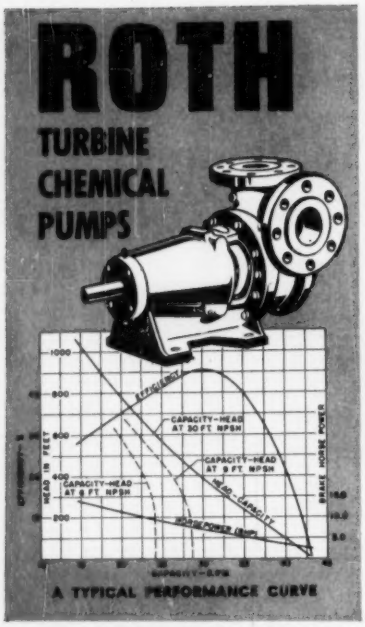


This new Bulletin No. 583 gives all the facts to help you select just the size and construction of valve for your air, gas or liquid lines. Illustrations—charts—tables are arranged in a practical, easy-to-use manner. Write for your copy.

ROCKWELL SINCE 1888 BUILT

W. S. ROCKWELL COMPANY
Valves - Butterfly · Slide · Diaphragm · Special
2369 ELIOT STREET • FAIRFIELD, CONN.

For more data on advertised products, use Readers' Service Cards, last page.



THE PERFORMANCE CURVE TELLS THE STORY!

ROTH Turbine Chemical Pumps are of single or two stage horizontal design, end-mounted for easy access. They are noted for their dependability and continuous high pressure service in the movement of clear liquids up to 100 cp viscosity under differential pressures up to 550 PSI . . . The single-stage turbine chemical pumps develop pressures comparable to those of multi-stage centrifugals and have established records for service under the most adverse conditions of corrosion and temperature surpassing those of far more costly pumps . . . Two-stage end-mounted chemical pumps are also available for a range from 300 PSI to 550 PSI differential pressure.

OIL LUBRICATED — Pumps have extra heavy, oil-lubricated ball bearings and shaft — are fitted with ASA rated flanged connections. Available with John Crane Seals, Dura-Seals, or packing. (Stuffing box easily demountable.)

RANGE
Head: 20 to 1200 ft.
Diff: 0 to 550
Cap: 1 to 140 GPM
Temp: −60° to +600° F.
H.P.: ¾ - 30 BHP
NPSH: as low as 3 ft.

USAGE
Hot and cold water
Acids
Caustic Solutions
Liquified Gases
Solvents
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MATERIALS
Stock Parts:
316SS; Hast. C; CI; steel; and bronze.
To Order:
304SS; 347SS; monel; nickel; NI-resist; and FA20

Write for
FREE
Technical Bulletin #100
Complete NPSH, seal, and mechanical data for ROTH Chemical Pumps — plus performance curves on all sizes.

ROY E. ROTH COMPANY
TURBINE PUMP DIVISION
2444 Fourth Avenue
Rock Island, Illinois

Equipment . . .

showing the strong and weak points of for acid, alkali, solvent, water, weathering, each. Accurate resistance ratings are listed flexibility, impact and abrasion, and temperature conditions. Compatibility over old paint, surface preparation and general comments are included.

Use of chart will help avoid incorrect selection of generic types and at the same time enable choosing the most effective protection for the plant. Carboline Co.

Circle E26 green card, last page

Complete Engineering Data Covered In Valve Catalog

Catalog KS1-M covering a complete line of Series Valves, has just been released. The 20-page booklet contains up-to-date data on cast steel gate, globe, angle, and swing check valves for refinery and petrochemical plant use.

Parts ordering information, trim material, recommended services, and a handy Figure Number Index designed for rapid reference are a few of the catalog features which will facilitate the ordering of valves.

If you use valves, this new catalog will be an asset to your work. Kerotest Manufacturing Co.

Circle E27 green card, last page

Jacketed Stainless Valves Described In Bulletin

Bulletin No. 3 describes a line of Aloyco 150 lb. and 300 lb. fully jacketed stainless steel valves designed for fluids difficult to move at room temperatures. All valves are integrally cast in a wide range of corrosive resistant alloys. Sectional view show gate, globe, and check valve designs, illustrating extensive jacketing, which includes bonnet areas. Teflon disc designs and flanged fittings, also available, are described and illustrated. Alloy Steel Products Co., Inc.

Circle E28 green card, last page

All-Molded PVC Valve Described In Brochure

A new, two-color, completely illustrated, six-page brochure describing Luncor valves, said to be the first all-molded corrosion-resistant PVC valve ever designed by a valve manufacturer, has been published.

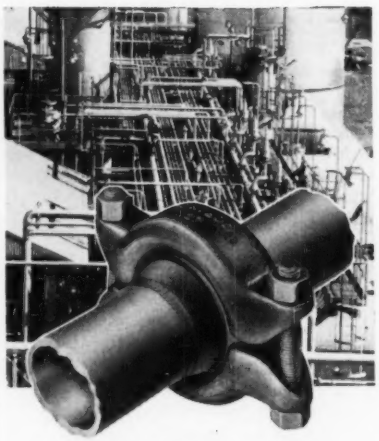
The new brochure features a table, giving the manufacturer's recommendations for handling various corrosive fluids with PVC valves; plus detailed information on sizes, weights and dimensions of both screwed and socket end PVC valves, and installation data. Lunkenheimer Co.

Circle E29 green card, last page

Epoxy Sprayed Over Glass Fibers Protects Vessels

The Matcote Process is a new method for coating tanks, vessels, acid pits, large diameter pipe and marine equipment. It produces a plastic-glass reinforced coating.

This coating is 100 percent non-volatile epoxies mixed with plastic resins. A spe-



GRAYLOC
New Principle of Pipe Connections

Two-bolt GRAYLOC Pipe Connections introduce a new principle in pipe make-up. Its design makes it possible for GRAYLOC to withstand full vacuum, high external pressure and extreme internal pressure. Moreover, this design makes it possible to make up GRAYLOC Connections repeatedly with no wear or other damage to the connections.

The bolting carries no primary force from internal pressures. Two bolts serve only to pull the connection together through the wedging action of the clamp and the seal ring.

Flexible tapered lips of the seal ring are angled slightly less than the mating hub. This forms a line seal which is changed to a surface seal as the connection comes together and the lips deflect.

GRAYLOC has practical uses in any application where flanges are used. GRAYLOC is recommended where pressures are high or where you want savings in money, space, weight or time.

For additional information, write, wire or telephone Gray Tool Company.

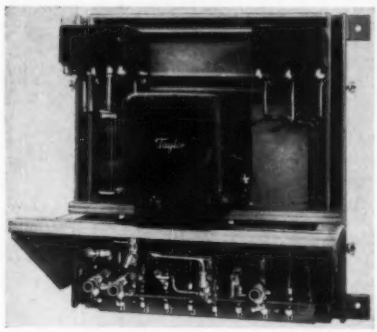
GRAY *Tool Company*
P. O. BOX 2291 HOUSTON, TEXAS
REpublic 4-1641 5903

cial machine developed by the company allows cold-spraying this mixture onto chopped glass fibers to form a non-corrosive interior or exterior lining.

Over 1,000 square feet of area can be coated to a ½-inch thickness in one hour. There is little or no shrinkage on curing.

The process is proved for upgrading oil and chemical storage tanks. Pitted, corroded storage tanks can be easily reconditioned. This coating stops water, acid, caustic and other chemical corrosion. Matcote Co.

Circle 30E green card, last page



Improved Fractionating Column Control Developed

The new Internal Reflux Computer Control System increases product uniformity, reduces steam consumption and the danger of column flooding as a result of its extra-ordinary ability to compensate for climatic effects on the reflux system and for cyclic fluctuations frequently occurring with conventional fractionator instrumentation.

Now, for the first time, a single analog computer provides a practical means of measuring and controlling the internal reflux flow from the top plate of a fractionating column. As the system is a relatively simple piece of equipment, first cost is moderate. Assembly from standard instruments and components also assures complete familiarity for servicing personnel. These factors notwithstanding, Taylor offers the internal reflux computer as the most efficient means yet devised of measuring and controlling internal reflux flow rate. High-speed computer operation allows ample time for correction of external reflux flow rate before the effects of change in internal reflux flow rate becomes significant.

Although internal reflux flow has an important effect on column operation, it has generally been an assumed value, determined principally by external reflux flow. The latter method is never entirely satisfactory because too many factors (change in top plate temperature, environmental changes such as rain storms, clouds passing, and day and night temperature variations . . . particularly with air-cooled condensers) all tend to distort any fixed ratio between internal and external reflux rates and temperatures.

The development of the Internal Reflux Computer is particularly timely because an ever-increasing number of Air-Fan cooled condensers are being installed as a result of the increasing costs of cooling water for use in condensers.

According to Phillips Petroleum Co. (developers and licensors of this system) many installations have rapidly paid for themselves on the basis of steam savings, where steam consumption formerly varied widely with conventional instrumentation. Phillips reports that additional computers are being installed on both water-cooled and air-cooled fractionators.

Peripheral measurements coupled with predetermined mathematical computations bring about accurate internal reflux flow rate measurement and control. Although the proper locating of these primary measurements is critical, fortunately optimum locations are in general a known factor.

A properly calibrated and installed computer eliminates disturbances in the reflux system and thus in column operation. This prevents excessive carry-over of heavier components into the product stream and assures maintenance of the necessary product composition.

Savings can be realized not only on steam costs but also on initial installation and routine maintenance. The computer also makes possible continuous fractionating column operation at very near flood point, for maximum output of high-quality, specification product with virtually no danger of actual flooding, due to a surge in reflux. Taylor Instrument Companies.

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52-Page Catalog Lists Chromatograph Instruments

Catalog 84 lists and describes more than 134 instruments and accessories available for gas and vapor chromatography. In addition, 158 different listings of partitioning agents are offered. This represents the largest collection of chromatographic instrumentation to be presented in a single volume thus far.

Featured in the publication is the Kromo-Tog, referred to as the most effective and versatile instrument of its kind for separating gas mixtures and certain liquid or solid compounds into component parts by elution chromatography.

Information in 52 pages includes an introduction to gas and vapor chromatography, a description of the Kromo-Tog flow system, a review of temperature programming and curves of typical analyses. Burrell Corp.

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Miniature Liquid Level Indicator Described

Bulletin WG-1824, Supplement B, describes a new miniature Transistorized Secondary Liquid Level Indicator.

The bulletin describes where it is used, how it works, construction details, advantages, weight, dimensions, and gives an installation diagram. Yarnall-Waring Co.

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by LLOYD E. BROWNELL and EDWIN H. YOUNG, both of the University of Michigan

A comprehensive guide to the efficient and economical design of vessels for the processing industries, this book presents the basic concepts, industrial practices, and analytical relationships useful in the design of processing equipment. The organization is based on the premise that the vessel is the basic part of most types of processing equipment. The scope extends from simple vessels for low-pressure and vacuum service to thick-walled vessels for high-pressure applications. The authors include derivations of relationships used as the basis of the A.S.M.E. code specifications.

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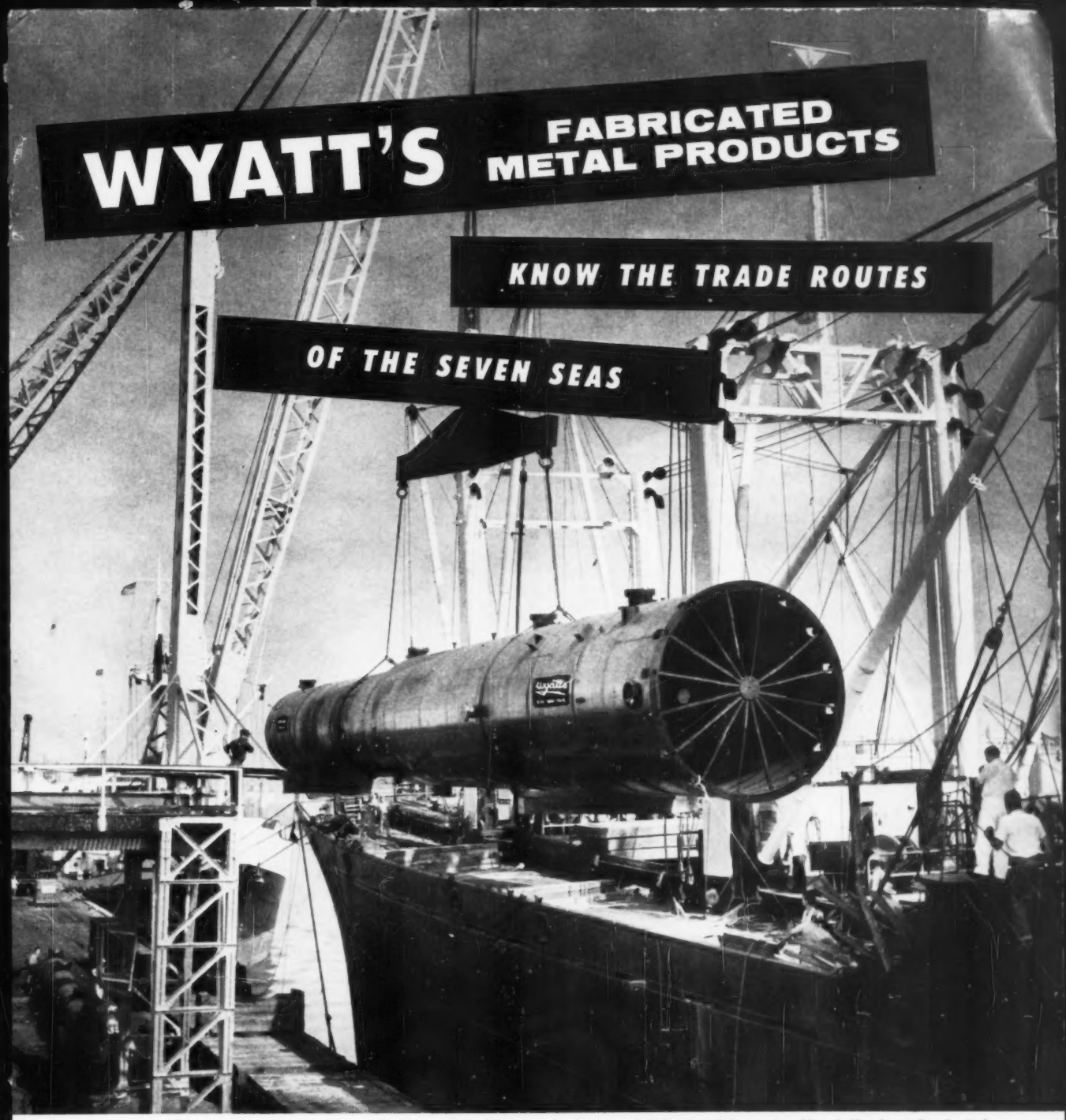

This 55-ton processing vessel being handled car to ship at the Long Reach dock, port of Houston, for foreign service.

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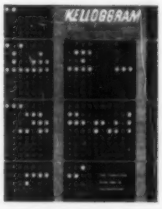
With this high speed digital computer on the staff, time no longer tells Kellogg engineers when their search for better process and mechanical designs should stop. Relieved of the burden of routine computation, engineers can put their creative and professional talents to greater use. Man-hours are more productive. Costs are lower. Above all, every Kellogg client is assured the optimum investment in his future plant.

Now, complex problems that once took days can be completed in minutes, and a greater number of alternative designs may be evaluated in seeking the ultimate. For example, a Kellogg computer study of an existing process examined 19 alternates and rechecked suggested modifications of each. All this ordinarily would have required hundreds of engineering man-hours over a period of about two months. With the computer, only two hours of machine time and few engineering man-hours were required to determine the optimum design.

Details on Kellogg's approach to engineering problems with the computer are documented in the current computer Kelloggram, available on request. For an historical review of the company's role in engineering and building oil refineries and chemical plants since 1901, ask for copy of oil centennial Kelloggram.



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